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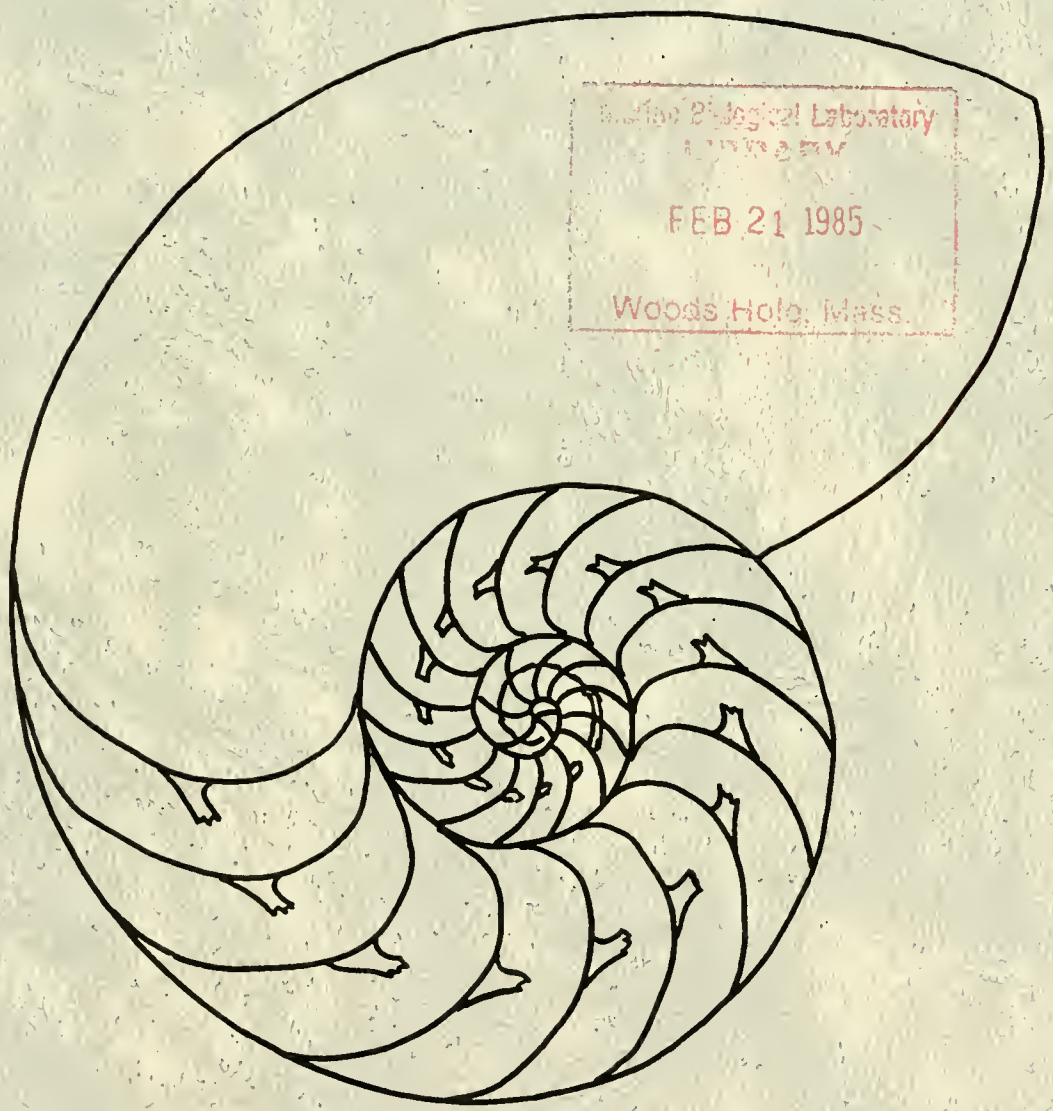

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1985 AMU Meeting

The American Malacological Union will hold its annual meeting on the campus of the University of Rhode Island on July 29-August 3, 1985. Three symposia will be presented: one on molluscan egg capsules, organized by Jan Pechenik; a second on molluscan radulae, organized by Robert Bullock and Carole Hickman; and a third on ecology of freshwater molluscs, organized by Eileen Jokinen. There will also be contributed papers, a poster session, marine and freshwater field trips, workshops, an auction, exhibits and commercial sales of items of interest, and a New England clam bake. A program to honor junior malacologists will open the meeting. The Boston Malacological Club is planning special events in commemoration of its 75th anniversary. For further information please contact Dr. M. R. Carriker, College of Marine Studies, University of Delaware, Lewes, DE 19958.

HUMAN MODIFICATION OF MOLLUSCAN HABITATS IN LITTLE CREEK ESTUARY, VIRGINIA

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ABSTRACT

Mollusks of Little Creek estuary in southeastern Virginia may be grouped into five assemblages indicative of the following benthic habitats: 1) fringe and embayed Spartina *marsh, 2) solid substrata (rock, pilings, shell), 3) intertidal muddy sand, 4) subtidal muddy sand, and 5) black organic mud.*

Human activities in the estuary such as dredging, stabilizing shorelines, landfilling, disposing of dredged spoil, and introducing foreign solid substrata have modified habitats and/or sediment character thus altering the distribution of molluscan assemblages.

Human activities within and around shallow estuaries of the southeastern U.S. may have substantial effects on the distribution and composition of bottom sediments. Substratum type exerts a strong control on benthic molluscan assemblages (Bird, 1970; Johnson, 1972). This paper correlates particular human activities with resultant changes in substratum and molluscan assemblage distribution in the western segment of Little Creek estuary.

Little Creek is typical of the numerous small estuarine systems in heavily urbanized areas of southeastern Virginia (Fig. 1). It is somewhat unusual in that it was formerly a freshwater lake (Pretty Lake) impounded behind the ocean

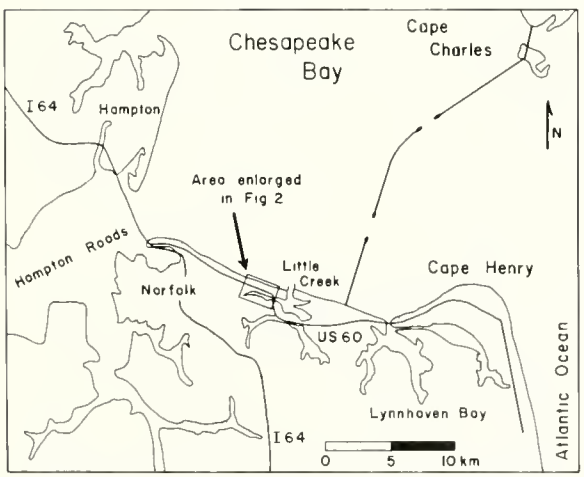

FIG. 1. Map of mouth of Chesapeake Bay showing location of Little Creek estuary and area enlarged in Figure 2.

view barrier-bar and dune complex. When the bar and dunes were breached by dredging, Pretty Lake became a broad shallow estuary. East of the bridge where U.S. route 60 crosses Little Creek, commercial development, mainly marinas, and the U.S. Naval Amphibious Base dominate the shoreline. West of the U.S. 60 bridge the original basin configuration has been less modified and the shoreline largely devoted to residential development. The western branch of Little Creek has about 21 km of shoreline of which about 26 percent (5.3 km) is narrow muddy beach, 51 percent (10.9 km) is fringe marsh, 18 percent (3.7 km) is embayed marsh, and 5 percent (1.0 km) is permanently stabilized by bulkheads and rip-rap (Owen and others, 1976). The preceding figures include a small amount of shoreline east of the bridge. Water depths over most of the western segment of Little Creek range from 0.5 to 1.5 m (MLW). Maximum depths of 1.7 to 2.5 m (MLW) were measured in channels under the bridge and to the north of the sand shoal near the bridge (Fig. 2). The tidal range is approximately 0.8 m. Surface salinities measured in August 1976 and 1977 ranged from 21 to 24‰ with the lower values in the marsh channels at the western extremity and highest values in the vicinity of the bridge. Salinities at the mouth of the estuary near the Little Creek jetties in Chesapeake Bay ranged from 22 to 24‰. Current velocities are greatest at the constriction produced by the bridge. No current measurements were made, but large ac-

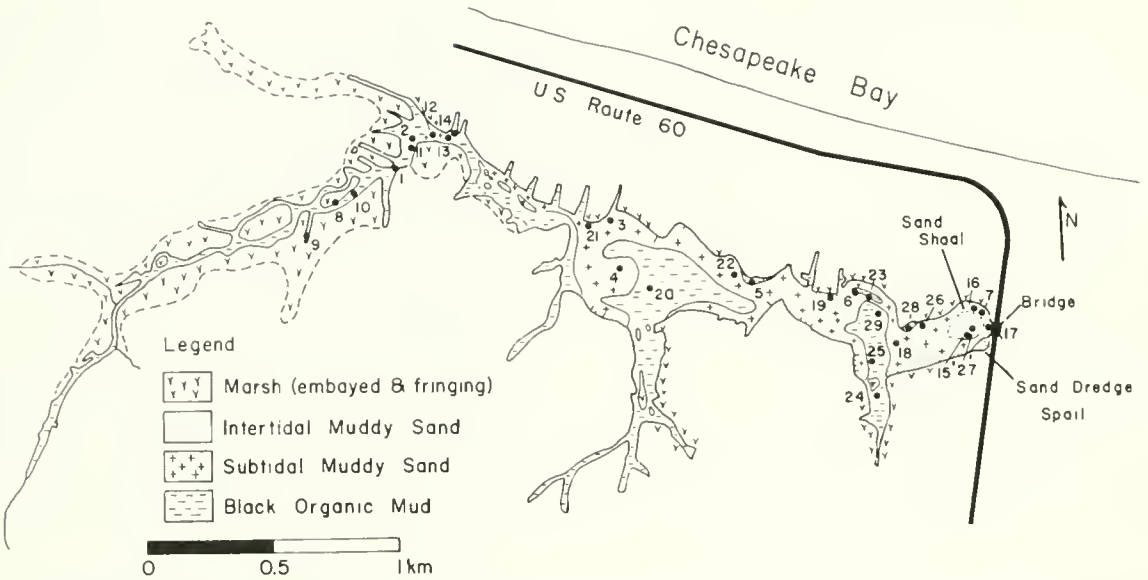

FIG. 2. Subenvironments and sediment distribution in western branch of Little Creek. Numbers give locations of mollusk and sediment samples.

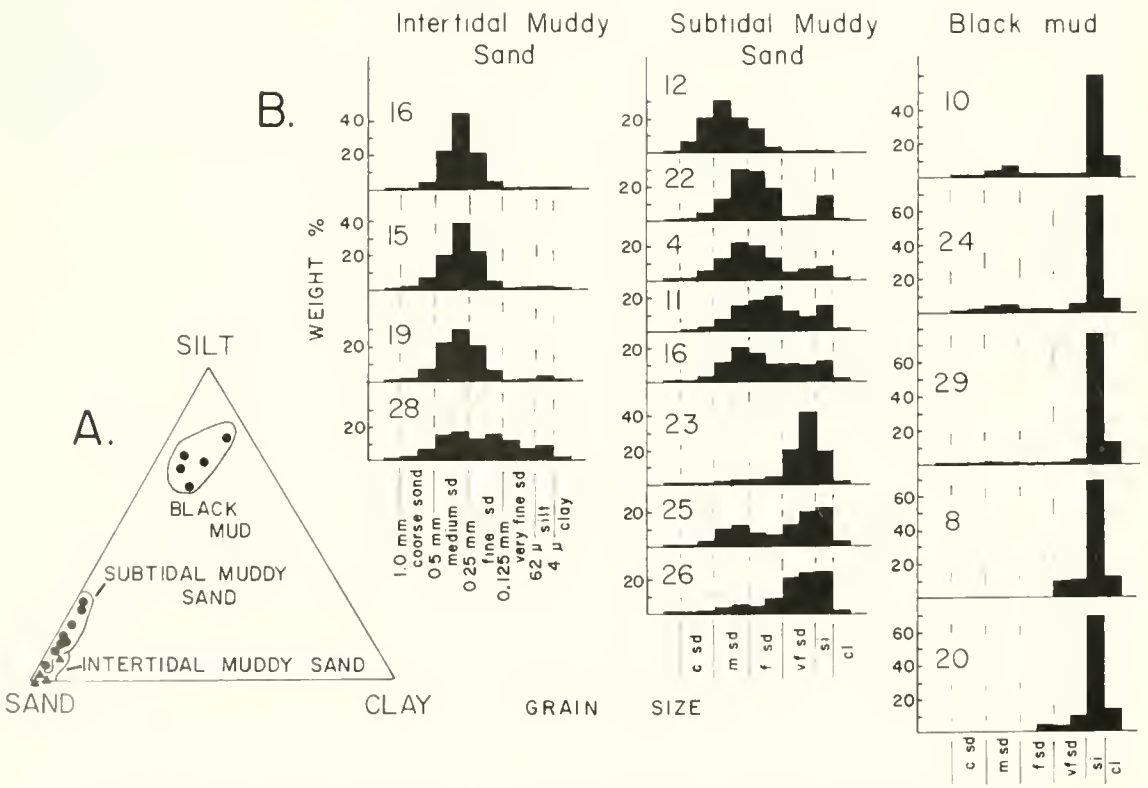

FIG. 3. Summary of sediment grain size analyses. Sand, silt, clay proportions of samples, A. Grain size distribution of sediments in subenvironments, B.

tive ripples (2-4 cm high) and observable sand transport on the surface of the shoal (Fig. 2) indicate moderate tidal currents. Muddy and silty sediments are indicative low current velocities in most other areas.

Sediment Distribution

Sediment samples were obtained at 29 stations (Fig. 2) and sediment types were mapped in the field at numerous locations along a longitudinal traverse from the bridge to station 10. The pattern of sediment distribution and sediment character is summarized in Figures 2 and 3. Coarsest sediment is found on the surface of the sand shoal (Fig. 2). Intertidal and subtidal muddy sands occur along the edges of the basin, as small bars, in channels, and in other areas where tidal currents are strong enough to prevent the accumulation of significant quantities of silt and clay. Black organic muds occur in marsh channels, dredged cuts off the main estuary, and in the central portion of the basin (Fig. 2). The black muds contain very large quantities of particulate organic detritus composed primarily of *Spartina alterniflora* and extrabasinal macrodetritus such as leaf litter. The extensive area of embayed marsh at the far western end of Little Creek baffles currents during flood tides and traps considerable quantities of mud.

Mollusk Distribution

Mollusks were collected with a 10 cm diameter pipe dredge or with a shovel in localities where water depth was less than 1 m. Samples were washed in the field on a 1 mm sieve. All mollusks retained were identified and counted. Species distribution for samples and relative abundance is given in Fig. 4. Due to lack of uniform sample volumes precise quantitative comparisons cannot be made among stations. All species listed were found living, but at many locations most specimens collected were dead individuals.

Species characteristic of major subenvironments are listed in Fig. 4. Note that some species, such as *Ilyanassa obsoleta*, achieve greatest abundance on intertidal and shallow subtidal muddy sand, but are common in other areas as well. The intertidal muddy sand, subtidal muddy sand, black organic mud sequence of subenvironments represents a substratum gradient from basin edge to basin center so it is not surprising to see strongly intergradational molluscan assemblages paralleling the gradient. Davies (1972) described a suite of molluscan assemblages from the Rappahannock River estuary that are very similar to those given in Fig. 4. Substratum type is only one of several important controlling factors. Predation also exerts a strong influence on the distribution of mollusks. Many estuarine species escape intense predation by living high in the intertidal zone (*Geukensia, Littorina, Crassostrea*), burrowing deeply into sandy substrata (*Mya, Tagelus*) or inhabiting soupy muds that are difficult for predators to search (*Macoma, Mulinia*). This flight from predation seems to be a strong secondary factor controlling the distribution of some estuarine mollusks. Shell damage due to predation by *Callinectes*, the blue crab, and possibly skates or rays was observed on some specimens of *Mercenaria* and *Mulinia*.

Bivalves common in the upper part of the intertidal zone attach to solid substrata by means of a byssus (*Geukensia, Ischadium*) or by cementation *(Crassostrea). Littorina* occurs in great abundance in the fringe marsh where it clings to *Spartina*. Large bivalves *Mercenaria, Mya*, and *Tagelus* are most abundant on sandy substrata capable of supporting their body mass. Rapid burrowers *Tagelus* and *Mya* are abundant in area of shifting substrata such as shallow subtidal bars and intertidal areas. *Crepidula* and *Anomia* are common in subtidal environments where rocks, shell, or foreign objects provide a solid substratum for permanent attachment. The black organic mud is a very soupy substratum that contains a very sparse bivalve fauna. Three species of *Macoma* and *Mulinia lateralis* have small enough whole animal mass to be supported by the mud (Stanley, 1970). *Macoma* is a deposit feeder that can utilize the abundant organic detritus of the black mud.

Modified and Unmodified Estuary

A cross-section of a composite unmodified shallow estuary is shown in Fig. 5A. This composite is based on relatively unmodified portions of Little Creek and on nearby estuaries that have undergone little modification. A typical profile includes a marginal fringing marsh with either muddy or sandy sediment depending on

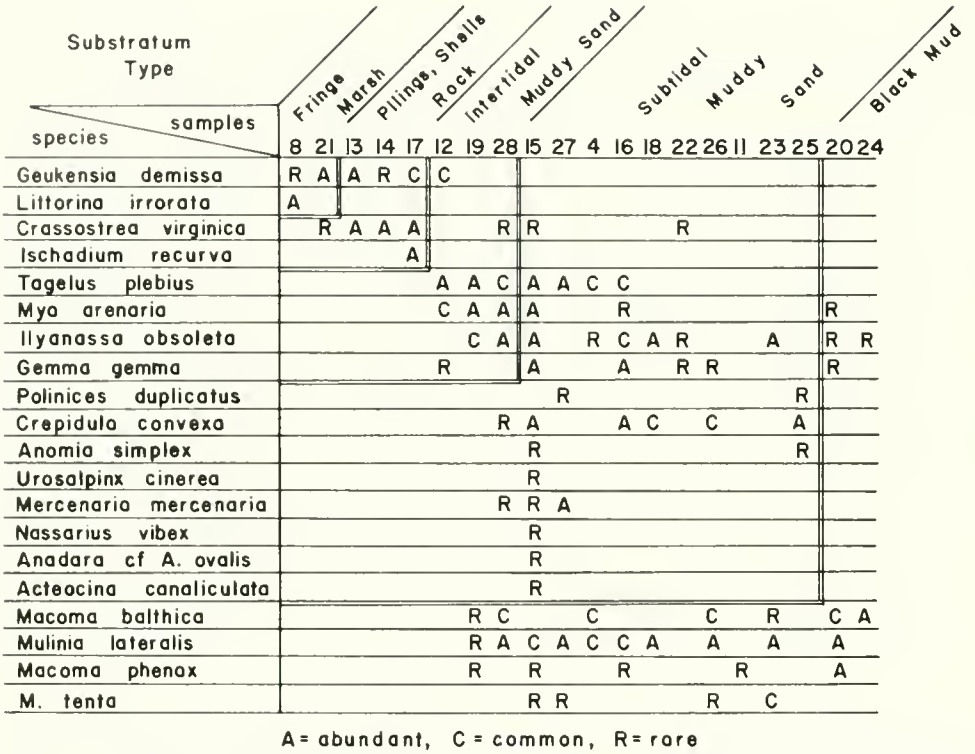
Substratum Type
Fringe Marsh
Pilings, Shells
Rock
Intertidal
Muddy Sand
Subtidal
Muddy
Sand
Black Mud
species
samples
8 21 13 14 17 12 19 28 15 27 4 16 18 22 26 11 23 25 20 24
Geukensia demissa R A A R C C
Littorina irrorata A
Crassostrea virginica R A A A R R R
Ischadium recurva A
Tagelus plebius A A C A A C C
Mya arenaria C A A A R R
Ilyanassa obsoleta C A A R C A R A R R
Gemma gemma R A A R R R
Polinices duplicatus R R
Crepidula convexa R A A C C A
Anomia simplex R R
Urosalpinx cinerea R
Mercenaria mercenaria R R A
Nassarius vibex R
Anadara cf A. ovalis R
Acteocina canaliculata R
Macoma balthica R C C C R C A
Mulinia lateralis R A C A C C A A A A
Macoma phenax R R R R A
M. tenta R R R C
A = abundant, C = common, R = rare

FIG. 4. Distribution of molluscan species in subenvironments. Double lines isolate species most characteristic for substrata at top of diagram.

local current energy. Subtidal margins are usually muddy sand with a silt and clay content determined by tidal current and wave activity. Small islands are produced where intertidal bars are stabilized by *Spartina*. The sandy intertidal zone grades into muddy sand of the shallow subtidal environment which, in turn grades into black organic mud near the center of the basin. Black mud or muddy sand is also the typical bottom sediment in the tidal channels that penetrate embayed marsh. In a natural estuary of the southeastern U.S. virtually the only solid substratum available is shell or wood fragments.

The following types of physical modification by man have altered the substratum and molluscan distribution in Little Creek:

Type of Change or Structure	*Affect on Subenvironment or Substratum*
1. Shoreline stabilization and landfill (bulkheads and rip-rap)	Reduces basin area Eliminates fringing marsh habitat Introduces solid substrata (rock and pilings) Introduces sand, silt and clay (during construction)
2. Dredging new marsh channels into embayed marsh and basin margin	Increases area of black organic mud Increases organic content of muds in open estuary
3. Bridge across estuary	Alters basin form Increases velocity of tidal currents that distribute sand and scour deep channels Introduces solid substratum
4. Refuse Disposal	Slightly increases quantity of solid substrata
5. Dredge spoil disposal	Increases grain size of sediment Causes shoaling of bottom

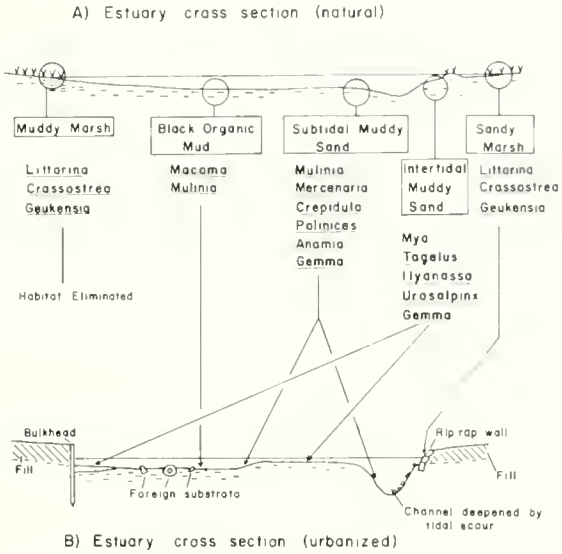

FIG. 5. Schematic estuary cross sections showing changes in molluscan habitats induced by man. Natural or undisturbed estuary, A, urbanized estuary, B.

Fig. 5B illustrates a composite cross-section of the natural estuary after urbanization. The basin has been reduced in area and much of the marsh habitat has been eliminated by "reclamation". This restricts the population size of the marsh fringe mollusks and affects the trophic dynamics and nutrient cycling in the system. Dredging or opening channels in embayed marsh allows tidal currents to remove coarser *Spartina* detritus and mats before it has thoroughly decayed or been modified by bacteria (Odum and LaCruz, 1967). Excess organic detritus settles into muds of the quiet central regions of the estuary producing anoxic bottom conditions. This process occurs naturally, but it is exacerbated by man's activities in the marsh. Marsh areas serve as a buffer to the estuarine system in that they reduce runoff and trap fine sediment (Welsh and others, 1978). Removing marsh from the basin, while increasing surface runoff in adjacent watershed areas, allows large quantities of silt and clay to be introduced and to accumulate in regions of low tidal energy. The mud bottom in the mid-reaches of Little Creek, around station 20, is covered with a very fluid flocculent layer of silt and clay up to 0.5 m thick. Such soupy substratum is usually inhabitated only by very rare individuals of *Macoma balthica*.

Due to the redistribution of sandy dredge spoil by tidal currents (Fig. 2) certain areas of Little Creek contain considerably more sand than would be expected in a natural estuary of comparable size. A substantial sand shoal and extensive areas of intertidal and subtidal muddy sand have enlarged the habitat of molluscan species prefering a coarser substratum. This might be viewed as a benefit in that the commercially exploitable species *Mya arenaria* and *Mercenaria mercenaria* are more abundant on sandy bottoms; however, unsatisfactory water quality hampers utilization of the shellfish resource (Owen and others, 1976).

Almost all solid substrata that are permanently exposed have been intensively colonized by mollusks. *Crassostrea virginica* is most abundant on introduced objects. There are no oyster "reefs" within Little Creek, but clumps of oysters established on foreign objects are dispersed over some intertidal and subtidal muddy sand flats. *Crepidula convexa* was found in great numbers on cans and other foreign metal substrata. Objects disposed of in the black mud provide support for molusks such as *Crepidula* that would not normally live in that subenvironment.

Summary

Human activities have significantly altered the distribution of mollusks in Little Creek by modifying basin configuration, hydrography, and substratum distribution. It appears that no molluscan habitat has been entirely eliminated, though all have been changed. The large area of *Spartina* marsh at the head of the creek is now protected by the Virginia Wetlands Act (Owen and others, 1976). Most dredging in the marsh predates this legislation. As the basin is now encircled by urban development future areal constriction is unlikely. In terms of the physical environment, Little Creek estuary and its molluscan community seems to be in a mature urbanized condition.

This study indicates the ease with which bottom types (substrata) may be characterized and mapped in a small estuary. The substratum distribution map successfully delimits the habitats potentially available to molluscan assemblages even though an expected assemblage may not fully occupy areas of preferred substratum at the instant of sampling. Changes in bottom type

associated with human acitivities in and around the estuary can be monitored easily and quickly, and the ultimate effect on molluscan species or assemblages can be predicted.

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MOLLUSCA OF FROG BAYOU, ARKANSAS

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ABSTRACT

Very few records of mollusks within the Arkansas River basin exist for Arkansas. Twenty-five species were collected from Frog Bayou, a small tributary of the Arkansas River in western Arkansas. The fauna is dominated by Interior Basin species with minimal influence from Interior Highlands endemics. However, southern affinities are represented.

The majority of malacological investigations within the Arkansas River drainage have been conducted in Oklahoma, Kansas, and Colorado (e.g. Isely, 1925; Murray and Leonard, 1962; Wu, 1978), while the lower portions of the basin remain largely unexamined. Within Arkansas, only a few incidental references to the occurrence of mollusks in this sytem have been published (e.g. Kraemer, 1976; Gordon, *et al.* 1980). The distribution of mollusks in Frog Bayou, a small Interior Highlands tributary of the Arkansas River in western Arkansas, is presented.

Materials and Methods

Frog Bayou drains portions of the extreme southern Ozark Plateaus and the northern slope of the Arkansas Valley (Ouachita Mountains province). The permanent flowing channel crosses the eastern half of Crawford County, Arkansas (Atoka sandstone). Substrates in upper Frog Bayou are quite rocky with large areas of exposed bedrock and rather high gradients. Middle portions are impounded by Lake Shepherd Springs (304 ha.) and Lake Fort Smith (212 ha.), while the mouth in inundated by

Ozark Lake of the McClellan-Kerr Arkansas River Navigation System. Lower Frog Bayou may be quite sluggish and include mud and sand substrate (Arkansas River aluvium). Collections were made by hand at 15 access areas along the permanently flowing portion (Figure 1). Additional records were obtained for Lake Fort Smith from ichthyoparasite slides prepared by Cloutman (1974). Voucher specimens are deposited at the University of Colorado Museum.

Results

Twenty-five species of mollusks were collected (Table 1). This included seven gastropods, 17 unionacean mussels, and *Corbicula fluminea* (Müller). The fauna above the reservoirs consisted only of pulmonates, primarily *Physella gyrina* (Say). Glochidial preparations by Cloutman (1974) indicate that *Quadrula pustulosa* (Lea) and *Anodonta grandis* Say occur in Lake Fort Smith. No other mollusks were collected from either reservoir. Lake Fort Smith is an impediment to water flow which may often be intermittent for several kilomenters downstream during late summer and early autumn. This area yielded only relicts of *Proptera purpurata* (Lamarck) and *Lampsilis hydiana* (Lea). The majority of species were found from Rudy downstream to the vicinity of Kibler. No mollusks were observed near the mouth.

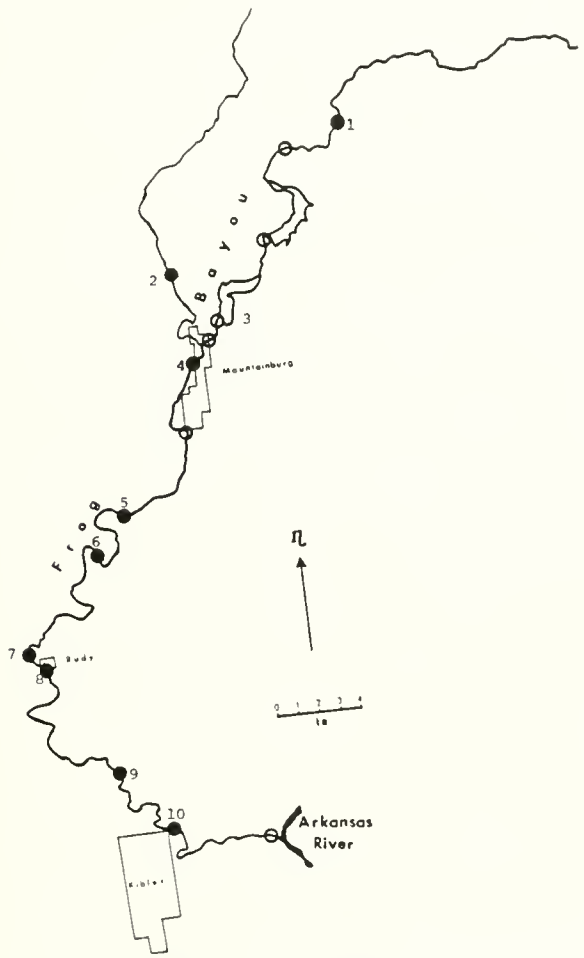

FIG. 1. Location of sampling stations on Frog Bayou, Crawford County, Arkansas. Open circles represent stations at which no mollusks were found.

Discussion

The molluscan fauna of Frog Bayou is composed primarily of widespread Interior Basin species. The only Interior Highlands endemic, *Elimia potosiensis* (Lea), oddly was found at the lowest sampling sight, rather than in rockier, higher gradient areas upstream representing more typical habitats for this species. A rather obscure species, *Menetus sampsoni* ("Ancey" Sampson), seems to be associated with the Interior Highlands but its distribution has not been clearly defined and may be more widespread (see Burch and Tottenham, 1980). *Ferrissia* cf. *arkansasensis* Walker also appears to be associated with the Interior Highlands. This form was synonymized under *F. rivularis* (Say) by Basch (1963) but seems to be a distinct species and may be found sympatrically with the latter. I have only been able to locate *F. arkansasensis* from a limited area of the Interior Highlands.

The unionacean component of Frog Bayou is strictly an Interior Basin fauna. There are no Interior Highlands endemics present and most are very common, widely distributed species. The presence of *Leptodea leptodon* (Rafinesque) establishes this species within the Arkansas River basin and geographically unites southern records (e.g. Wheeler, 1918; Isely, 1925) with northern populations. It also suggests that Call's (1885: see Scammon, 1906; Murray and Leonard, 1962) record may have been valid for Kansas (Neosho River). Additionally, a southern affinity is represented by three species: *Proptera purpurata*, *Lampsilis hydiana*, and *L. satura* (Lea). *Proptera purpurata* and *L.*

TABLE 1. Mollusca of Frog Bayou, Arkansas. (See Fig. 1 for station localities.

	Station: 1	2	3	4	5	6	7	8	9	10
Class Gastropoda										
Family Pleuroceridae										
Elimia potosiensis (Lea)										X
Family Lymnaeidae										
Fossaria obrussa (Say)	X									
Family Physidae										
Physella gyrina (Say)	X	X								X
Family Planorbidae										
Menetus sampsoni ("Ancey" Sampson)	X									
Helisoma anceps (Menke)		X								
Family Ancylidae										
Ferrissia rivularis (Say)	X									
Ferrissia cf. *arkansasensis* Walker	X					X		X		
Class Bivalvia										
Family Amblemidae										
Subfamily Ambleminae										
Fusconaia flava (Rafinesque)					X	X	X	X		X
Quadrula pustulosa (Lea)			X				X	X		X
Tritogonia verrucosa (Rafinesque)					X	X	X	X		X
Amblema plicata (Say)										X
Subfamily Lampsilinae										
Obliquaria reflexa Rafinesque							X		X	
Actinonaias ligamentina (Lamarck)							X	X	X	X
Truncilla truncata Rafinesque							X		X	
Leptodea fragilis (Rafinesque)										X
Leptodea leptodon (Rafinesque)							X			
Proptera purpurata (Lamarck)				X				X	X	X
Lampsilis teres (Rafinesque)							X		X	X
Lampsilis hydiana (Lea)				X			X	X	X	X
Lampsilis satura (Lea)						X	X		X	X
Family Unionidae										
Subfamily Anodontinae										
Anodonta grandis Say			X							
Lasmigona costata (Rafinesque)							X			X
Alasmidonta marginata[1] (Say)										X
Subfamily Strophitinae										
Strophitus undulatus (Say)								X		X
Family Corbiculidae										
Corbicula fluminea (Müller)						X	X	X		X

[1] Strophitini Gordon (1981) is elevated to subfamilial status.

hydiana appear to replace *P. alata* (Say) and *L. radiata siliquoidea* (Barnes), respectively, in the south. *Lampsilis satura* is closely related to (and often confused with) *L. ventricosa* (Barnes), representing a southern clinal variation probably fitting within the model presented by Cvancara (1963). While these three species are members of the Interior Basin fauna, they only range north to approximately 38°30′ N. latitude and have colonized Gulf coastal systems east and west of the Mississippi River. Thus, the Arkansas River appears to have served as a corridor through the Interior Highlands for dispersal of both common Interior Basin species and a more restricted southern component.

Acknowledgments

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A NEW SPECIES OF *PYGMAEPTERYS* VOKES FROM THE WESTERN PACIFIC (GASTROPODA: MURICIDAE)

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ABSTRACT

A new species of Pygmaepterys, P. bellini, *from off Okinawa and the Philippine Islands, is described. Comparison is made with* P. funafutiensis *(Hedley, 1899), and* P. philclover *(Houart, 1984), both western Pacific congeners.*

Vokes (1978) erected *Pygmaepterys* as a subgenus of *Pterynotus* Swainson, 1833, describing this subgenus as small for a *Pterynotus*, with six winged varices, strong spiral cords and numerous axial lamellae; the aperture denticulate on the outer lip and "occasionally small denticles on the inner lip." She designated *Pygmaepterys alfredensis* (Bartsch, 1915) as the type species. *P. alfredensis* is a small six-mm specimen, very worn, with the early whorls and varices eroded. The shoulder is concave and the suture deeply impressed. There are 12 major cords on the body whorl. *P. alfredensis* is illustrated in Vokes (1978) pl. 7, figs. 1a, 1b, 2a and 2b and in Vokes and D'Attilio (1980) pl. 2, figs. 1a and 1b. The type locality is Port Alfred, South Africa. Apparently additional specimens have not been found of this species. Bartsch (1915) in his original description of *P. alfredensis* mentions no denticles on either the inner lip or the outer lip of the aperture.

Vokes and D'Attilio (1980) described three new species of *Pygmaepterys* and assigned one other species to the genus, but expressed some doubts regarding the qualitative character of the inner lip denticles.

As a result of the species studied for this paper we have concluded that although denticles in the outer lip are a good character of the genus, *Pygmaepterys*, the presence or absence of nodes or denticles on the inner lip or columella is inconsistent.

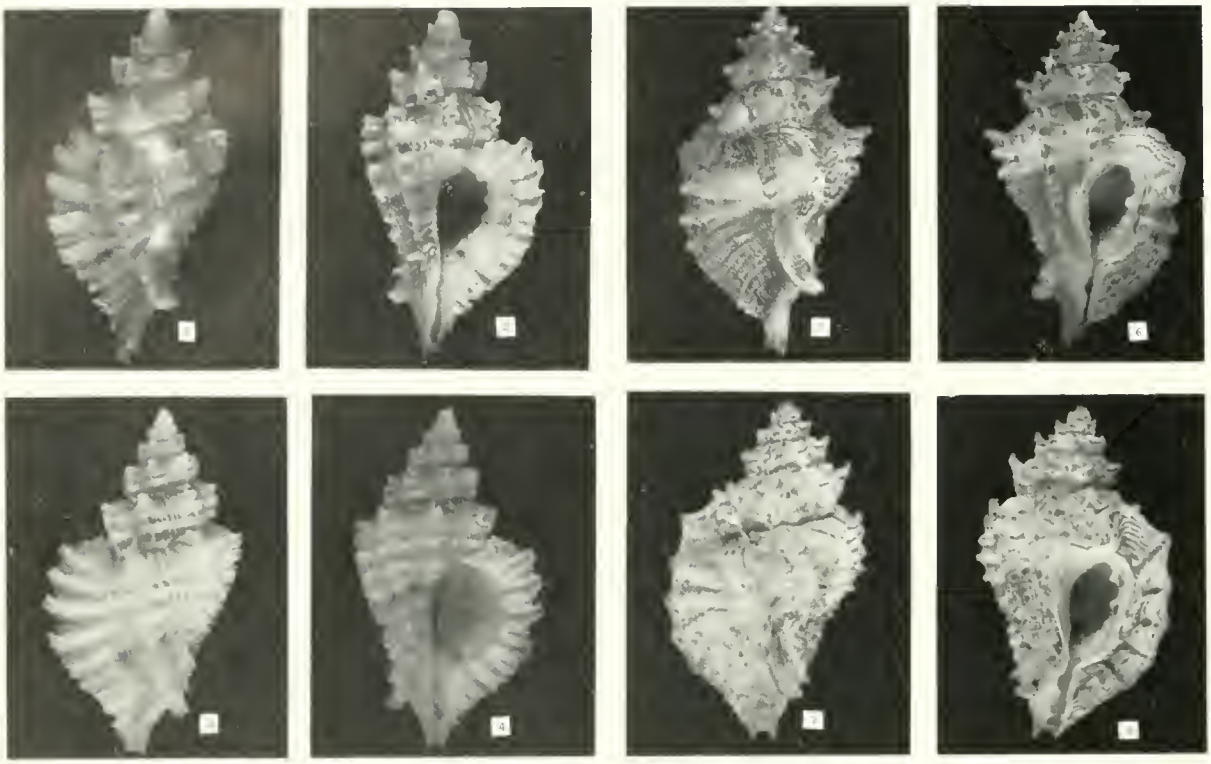
The following abbreviations are used:
SDNHM – San Diego Natural History Museum
AMNH – American Museum of Natural History, New York.

Family Muricidae Rafinesque, 1815
Subfamily Muricopsinae
Radwin and D'Attilio, 1971
Genus ***Pygmaepterys*** Vokes, 1978

Type species: *Murex alfredensis* Bartsch, 1915, by original designation.

Pygmaepterys bellini *new species*
Figs. 1-4, 9, 12

Description: Shell small, fusiform; spire elongate with four convex post-nuclear whorls;



FIGS. 1 and 2. *Pygmaepterys bellini* D'Attilio and Myers. Dorsal (**1**) and apertural (**2**) views of holotype, SDNHM 83065. Okinawa, Japan. 9.9 mm × 5.5 mm.

FIGS. 3 and 4. *Pygmaepterys bellini* D'Attilio and Myers. Dorsal (**3**) and apertural (**4**) views of paratype SDNHM 83067a. Philippine Islands. 12.0 mm × 5.5 mm.

FIGS. 5 and 6. *Pygmaepterys phileloveri* (Houart, 1984). Dorsal (**5**) and apertural (**6**) views. SDNHM 83068. 13.7 mm × 8.00 mm.

FIGS. 7 and 8. *Pygmaepterys funafutiensis* (Hedley, 1899). Dorsal (**7**) and apertural (**8**) views of specimen from the Donald Pisor collection. 12.0 mm × 7.2 mm.

suture impressed. Protoconch of one and one-half smooth convex whorls, white in color. Aperture narrowly ovate; anal sulcus broadly U-shaped; inner lip mostly appressed except very slightly erect anteriorly with one strong node on columella at entrance to the canal; entire columella stained dark-brown. Outer lip wavy, reflecting the external spiral cords with six strong nodelike denticles within. Siphonal canal open, tapered and recurved. Three distal portions of previous canals terminate on siphonal fasciole. Six axial varices per whorl irregularly descend relative to axis of shell. A few well-defined erect lamellae occur between the varices and a few regularly-spaced translucent lamellae crowd against the leading side of the varix. These lamellae undulate over the spiral sculpture giving a scabrous appearance to the shell. Eleven strong regularly-spaced spiral cords with equally wide interspaces occur on the body whorl; intermediate minor spiral cords occur only on the varical flange. The color of shell varies from translucent white to white with one to three brown stripes on the body whorl.

Type Material: Holotype SDNHM 83065 from Okinawa, Ryukyu Islands, Japan (Figs. 1, 2, 9, 12). Paratype SDNHM 83066a and Paratype 83066b from Okinawa. Paratype SDNHM 83067a from the G. Everson collection from Philippine Islands (Figs. 3, 4). Paratype SDNHM 83067b from B. Myers collection from Philippine Islands. Paratype AMNH 213704 from Okinawa.

Type Locality: 52 meters depth off Okinawa, Ryukyu Islands, Japan.

Dimensions (in mm):

	Length	Width
SDNHM 83065	9.9	5.5
SDNHM 83066a	10.2	4.8
SDNHM 83066b	7.9	4.9
SDNHM 83067a	12.0	7.0
SDNHM 83067b	9.9	5.5
AMNH 213704	8.0	4.5

Etymology: Named for Mr. Philip Bellin of Hawaii who first collected specimens off Okinawa, Japan.

Discussion: Of the six specimens studied, three have immature lips with no nodes or denticles. Paratype 83066a has six denticles on the outer lip and three nodes on the anterior wall of the columella. Paratype 83066b has seven denticles on the outer lip and one node on the columella at the entrance to the siphonal canal.

Comparison is made with *P. funafutiensis* (Hedley, 1899). See Table 1. The type specimen of *P. funafutiensis* is from Funafuti Atoll, Ellice Islands and is 9 mm in height. Specimens in the San Diego Natural History Museum, lot #71304, dredged from 183 m in Pokai Bay, Oahu, Hawaii, consist of four specimens, the larger of which is 9.8 mm × 6.2 mm and two fragments. Both the type specimen from Ellice Islands and the larger specimen from Hawaii are illustrated in Vokes and D'Attilio (1980), pl. 2, figs. 4, 5a and 5b. *P. funafutiensis* has a heavier coarser shell with six axial varices and five postnuclear whorls. There are five strong spiral cords on the body whorl with wide interspaces, each interspace with five to seven incised lines. *P. bellini* has 11 regular, moderately strong cords with equal interspaces and intermediate cords only on the varical flange. Growth lamellae in *P. funafutiensis* are close-set and three to four times as numerous as in *P. bellini*. *P. funafutiensis* has five apertural denticles on the outer lip; the first and second denticles posteriorly are most prominent. *P. bellini* has six denticles of even strength. The columella of *P. funafutiensis* lacks any trace of the brown stain prominent in *P. bellini*. The color of *P. funafutiensis* is tan with a diffused brown band subsuturally and one at the base of the body whorl. A specimen of *P. funafutiensis* from the Philippine Islands in the collection of Donald Pisor of San Diego, California, measures 12 mm × 7.2 mm (Figs. 7, 8, 11, 14). This specimen does not differ in any essential respect from those from Hawaii except that

TABLE 1. Comparison of *Pygmaepterys bellini* new species, *P. philcloveri* Houart and *P. funafutiensis* (Hedley).

	P. bellini	*P. philcloveri*	*P. funafutiensis*
Color:	All white or white with brown bands and with brown stain on columella	Rust brown with pale brown band; columella white, no brown stain	Tan with brown band, columella white, no brown stain
Shape:	Fusiform, spire elongate	Fusiform, spire moderately elongate	Fusiform, spire moderately elongate
Size:	To 12.0 mm × 7.0 mm	To 13.7 mm × 8.0 mm	To 12.0 mm × 7.2 mm
Protoconch:	White, 1½ blunt whorls	Tan, 1¾ conical whorls	Brown, 1½ low depressed whorls
Postnuclear whorls:	Four	Five	Five
Varices:	Six, irregularly descending	Six, regularly descending	Six, regularly descending
Peristome:	Simple ovate, inner lip appressed slightly erect anteriorly	Irregularly ovate, inner lip erect, flattened posteriorly	Simple ovate, inner lip mostly appressed
Anal sulcus:	Shallow and broad	Moderately broad and deep	Broad and deep
Varical flange:	Very weakly lamellose reflecting the numerous spiral cords	Entirely scabrously lamellose reflecting the numerous spiral cords	Five deep grooves, reflecting the five strong spiral cords
Suture:	Impressed	Moderately impressed	Moderately impressed
Denticles:	Six on outer lip, one on columella	Six on outer lip, five on columella	Five on outer lip, two on columella
Growth lamellae:	A few erect lamellae appressed over the spiral cords	Numerous erect lamellae appressed over the spiral cords	Very numerous lamellae appressed over entire shell
Spiral cords:	Eleven moderately strong cords terminating at end of siphonal canal	Twelve major cords terminating at tube-like portion of siphonal canal	Five major cords followed by five minor cords terminating at end of siphonal canal

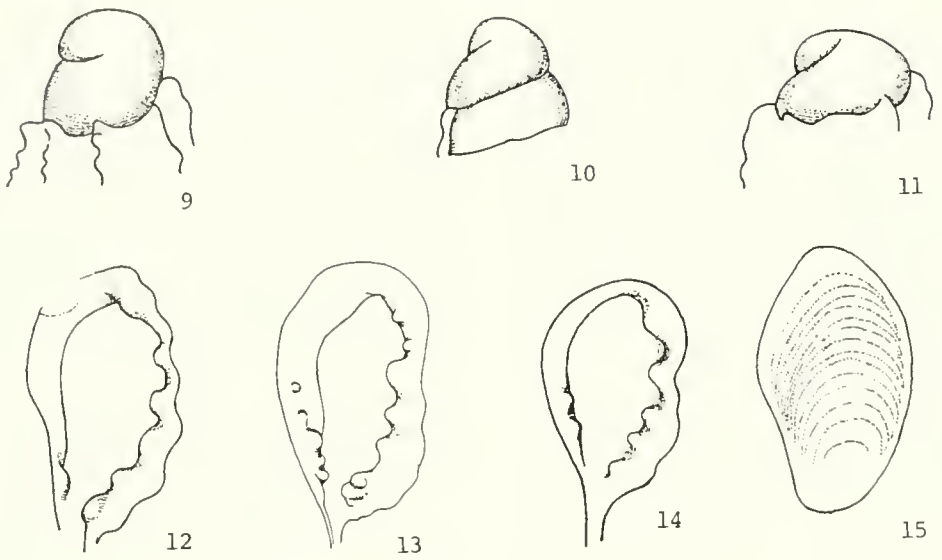


FIG. 9. Detail drawing of protoconch of *P. bellini*. Holotype SDNHM 83065.
FIG. 10. Detail drawing of protoconch of *P. philcloveri*. SDNHM 83068.
FIG. 11. Detail drawing of protoconch of *P. funafutiensis*. Donald Pisor collection.
FIG. 12. Detail drawing of aperture of *P. bellini*. Holotype SDNHM 83065.
FIG. 13. Detail drawing of aperture of *P. philcloveri*. SDNHM 83068.
FIG. 14. Detail drawing of aperture of *P. funafutiensis*. Donald Pisor collection.
FIG. 15. Detail drawing of operculum of *P. philcloveri*. SDNHM 83068.

nodes on the columella number two instead of three.

A second new species of *Pygmaepterys* had been under study by us. A description of this species has recently been published by Houart (July, 1984). The description prepared by us follows:

Pygmaepterys philcloveri (Houart, 1984)

1984 *Poirieria (Pazinotus) philcloveri* Houart, Informations, series 12, nos. 2, 3, pp. 127-130. (off Samal Id., Davao, Mindanao Id. Philippines).

Figs. 5, 6, 10, 13, 15

Description: Shell strongly fusiform, spire moderately elongate, suture moderately impressed. Protoconch of one and three-fourths conical, convex smooth, pale brown whorls; five post nuclear whorls. Anal sulcus u-shaped and deep. Inner lip appressed posteriorly, strongly erect two-thirds distance from siphonal canal; five elongate denticles occur on lower portion of columella, the most anterior denticle situated directly above the entrance to siphonal canal. Outer lip erect, wavy, reflecting the external spiral sculpture with six denticles arranged as follows: two small denticles posteriorly followed by a very large denticle midway, two slightly smaller denticles below and a large bifid denticle above entrance to siphonal canal. Siphonal canal open, broad and tapering distally becoming recurved and tubelike. Three distal portions of previous canals terminate on siphonal fasciole. Seven axial varices on spire diagonally descend to the body whorl where the varices number only six. Varices blade-like continue above the shoulder and abut the suture. Entire surface of shell with very fine scabrous close-set axial growth lamellae. Spiral sculpture of 12 cords starting at shoulder; first five prominent and somewhat spinose at the varical margins with prominent open spines at the shoulder; interspaces wide; remaining seven cords narrower and more close-set with diminishing interspaces. Operculum typically Muricopsinae.

Color: Rust-brown with a pale band starting at the shoulder and encompassing the first three cords. The rust-brown is much darker below the suture. The distal portion of the canal is gray-white and the aperture is white. Length of shell 13 mm.

Discussion: P. philcloveri in comparison with *P. bellini* has a slightly larger, more robust

shell. See Table 1. The shell is distinguished most significantly in the apertural characters. The aperture of *P. philcloveri* is irregularly ovate and the inner lip strongly erect over most of its length. There is a deep anal sulcus in comparison to the broad shallow sulcus of *P. bellini*. Although the number of denticles is the same, the arrangement and size differ in that *P. bellini* has six denticles of equal strength, while *P. philcloveri* has two small denticles posteriorly followed by a very large denticle midway on the outer lip with two smaller denticles following and one large bifid denticle above the entrance to the siphonal canal. *P. bellini* has six varices irregularly descending to the body whorl, while *P. philcloveri* has seven regularly descending axial varices on the spire reduced to six on the body whorl, the varix lacking is between the final varix and the preceding one. The entire surface of *P. philcloveri* consists of fine, strong, closeset scabrous lamellae in contrast to the few translucent erect lamellae of *P. bellini*. The overall brown stain on the columella of *P. bellini* is not found in *P. philcloveri*. *P. bellini* has a white shell with three brown bands and *P. philcloveri* has a rust brown shell with a pale brown band.

P. funafutiensis (Hedley, 1899) differs from *P. philcloveri* in the protoconch which is depressed and not conical. The inner lip of *P. funafutiensis* is mostly appressed, not erect as in *P. philcloveri* and there are five denticles on the outer lip of more or less equal strength in contrast to the six denticles of unequal size and strength of *P. philcloveri*. The spiral sculpture of *P. funafutiensis* consists of five very strong major cords with five minor cords while *P. philcloveri* has 12 strong major cords. The growth lamellae of *P. funafutiensis* are very numerous and appressed over the entire shell, whereas in *P. philcloveri* the lamellae are erect and only appressed over the spiral cords. The leading side of the apertural varix of *P. funafutiensis* has five strong concave troughs, a reflection of the strong exterior cords. The apertural varix of *P. philcloveri* is regularly wavy reflecting the spiral cords.

Acknowledgments

We wish to thank the following: Mr. Philip Bellin of Hawaii for donating specimens of *Pygmaepterys bellini* new species to the Natural History Museum of San Diego; Mr. Gene Everson of Lauderhill, Florida, for donating his specimen of *P. bellini* from the Philippine Islands; Mr. Victor Dan of Manila, Philippine Islands, for allowing us to study his specimens of *P. philcloveri* and for donating a specimen to our museum; Mr. Robert Yin of La Jolla, California, for bringing the specimens of *P. philcloveri* to our attention; Mr. Donald Pisor of San Diego, California, for allowing us to study his very fine example of *P. funafutiensis* (Hedley, 1899). We are grateful to Mr. David K. Mulliner for the photography used in this paper. Dr. William K. Emerson and Mr. Walter E. Sage, III of the American Museum of Natural History read a draft of the manuscript.

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MUREX HAMATUS HINDS, 1844, A LIVING WEST AMERICAN SPECIES ASSIGNED TO THE NEOGENE PACIPHILE GENUS, *PTERORYTIS* CONRAD (GASTROPODA: MURICIDAE).

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ABSTRACT

Pterorytis hamatus *(Hinds), an inhabitant of Ecuadorian and Peruvian waters, is the only known extant species of this muricacean genus.* Pterorytis *was widely distributed in the tropical western Atlantic during the Neogene. By the end of the Pliocene, however, the constituents of this Paciphile genus apparently became extinct in the western Atlantic, with* P. hamatus *surviving on the Pacific side of the Panamanian land bridge. The typological specimens of* Murex hamatus *were examined, and a live-collected specimen was studied. On the basis of opercular, radular and shell characters, the assignment of this species to the muricid subfamily Ocenebrinae is confirmed.*

Some twenty-five years have passed since my review of the muricid genus *Pterorytis* appeared (Emerson, 1959). At that time the genus was believed to consist of extinct east American Neogene species. More than a decade ago, however, Vokes (1971, pp. 56, 141, and Vokes *in* Keen, 1971, p. 536) recognized that a long-misunderstood species from Ecuador, described by Hinds in 1844 as *Murex hamatus*, was a living representative of this Paciphile genus. Previously, Hinds' species was referred to other muricid genera, including *Tritonalia*, *Ocenebra* and *Ceratostoma* and was erroneously placed in the synonymy of *Ceratostoma lugubre* (Broderip, 1833), a species that also was originally described from Ecuador.

Through the kindness of Carol Skoglund of Phoenix, Arizona, a specimen of *Pterorytis hamatus*, taken alive by shrimpers working out of San Pablo, Ecuador, was submitted to me for study. As the preservation of the soft parts of this specimen presented an opportunity to establish the taxonomic placement within the Muricidae of this rarely found species, the present study was undertaken.

Family Muricidae Rafinesque, 1815
Subfamily Ocenebrinae Cossmann, 1903

Genus ***Pterorytis*** Conrad, 1862
Pterorytis hamatus (Hinds, 1844)

Figs. 1-5, 7-9

Murex hamatus Hinds, 1844a, p. 128; Hinds, 1844b, p. 8, pl. 3, figs. 11, 12; Reeve, 1845, *Murex*, sp. 119, pl. 27, fig. 119 ("Museum Belcher"); Sowerby, 1879, *Murex*, sp. 203, p. 44, pl. 16, fig. 159 ("Voy. Sulph., p. 8").

Murex lugubris Broderip, Tryon, 1880, p. 124, pl. 37, fig. 439 only; Keen 1958, p. 357, in part. Not *M. lugubris* Broderip, 1833.

Tritonalia hamata (Hinds), Dall, 1909, p. 220, "Guayaquil, Ecuador, and south to Paita, Peru"); Smith, 1939, p. 15, (cites Dall's distributional data).

Ceratostoma hamata (Hinds), Keen, 1966, p. 269, pl. 46 fig. 11 ("figured syntype, from Belcher coll. to S. Hanley to H. Harvey; also figured by Reeve, [1845]").

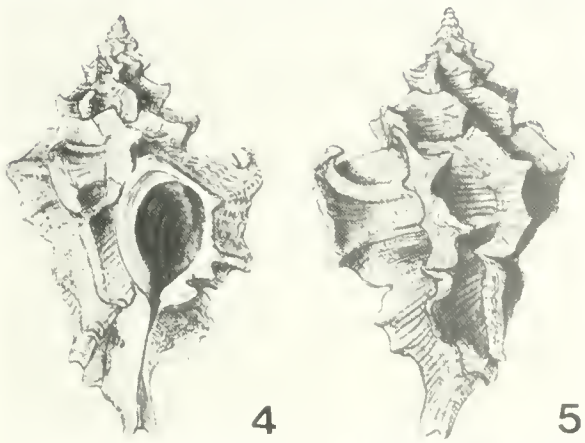
Pterorytis hamatus (Hinds), Vokes, 1971, pp. 56, 141; Keen, 1971, p. 536, fig. 1039 ("BM Syntype", p. 951); Fair, 1976, p. 47, pl. 23, fig. 360 ("BM(NH) Holotype (EH V[okes])", p. 134).

Ocenebra? hamata (Hinds), Radwin and D'Attilio, 1976, pp. 121, 122, pl. 14, fig. 2 ("off Peru, Inst. Del Mar, Peru," p. 259).

Type locality: "Bay of Guayaquil, [Ecuador], from a muddy floor, in twenty-one fathoms" [38 m].

Known range: Golfo de Guayaquil (type specimens) and off San Pablo, Guayas Province (AMNH 213692), Ecuador, and Paita, Peru (Dall, 1909, p. 220; cited specimens were not

FIGS. 1–3. *Pterorytis hamatus* (Hinds, 1844), off San Pablo, Guayas Province, Ecuador (AMNH 213692); height = 38.6 mm.



FIGS. 4 and 5. Original figures of *Murex hamatus* (Hinds, 1844b, figs. 11, 12); height = 29.2 mm.

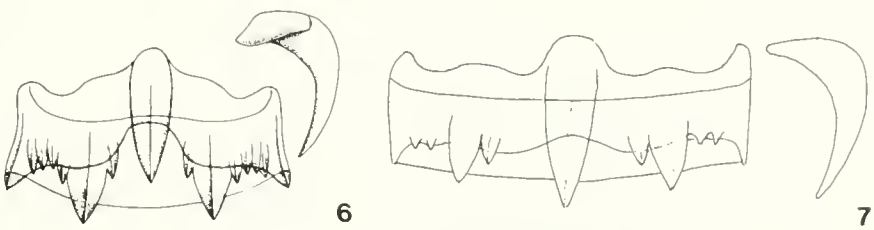
found in the NMNH collection, *teste* J. Rosewater, August 10, 1984).

Diagnosis: Shell rhomboid in outline, 23 mm to 40 mm in height. Spire elongated, of 3½ nuclear whorls; 4 post nuclear whorls. Six raised, spiniform varices per whorl ornamented with slightly recurved laciniations and one or two major ribs on faces of varices. Aperture oval, with an acute labial tooth anteriorly, marked here and on the previous varices of body whorl by a V-shaped notch behind varical tooth. Canal short, closed, grooved behind. Color pale-yellow to tan (modified after Fair, 1976, p. 47).

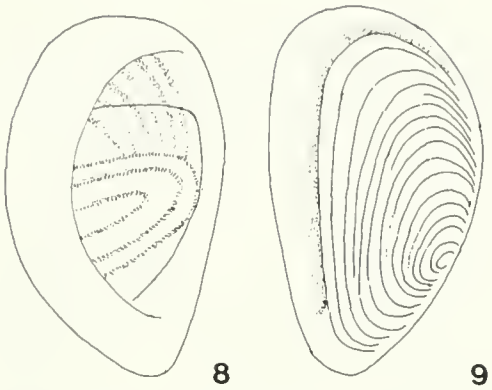
Radular characters: Typical of Ocenebrinae; compare our Figure 7 with our Figure 6 of the radular dentition of *Ocenebra erinaceus* (Linné, 1758), the type species of *Ocenebra* Gray, 1847.

Opercular characters: Ocenebrine, see Figs. 8, 9.

Remarks: The larger of the two "syntypes" of *Murex hamatus* in the British Museum (Natural History) (1907.12.30.134, here illustrated, Figures 4, 5), measures 29.2 mm (*sans* nucleus). This specimen (29.2 mm in length) appears to be the one figured by Hinds (1844b, pl. 3, Figs. 11,



FIGS. 6 and 7. **6**, Radular dentition of *Ocenebra erinaceus* (Linné, 1758), after Radwin and D'Attilio, 1976, fig. 73. **7**, Radular dentition of *Pterorytis hamatus* (Hinds, 1844), (AMNH 213692), drawing by Anthony D'Attilio. left side, central tooth; right side, 1 lateral tooth.



FIGS. 8 and 9. Operculum of *Pterorytis hamatus* (Hinds, 1844), (AMNH 213692), left side, internal view; right side, external view; drawings by Anthony D'Attilio; greatly enlarged.

12) and Reeve (1845, *Murex*, pl. 27, Fig. 119), despite the fact that Hinds (1844a, p. 128) cites 13½ English lines for the axis of the shell [= 28.5 mm]. 13.5 French lines would be 30.3 mm. Keen (1966, p. 269) translated it to 34 mm. Keen (*op. cit.*) also recorded a second specimen, a topotype, in the general collection of the British Museum (1842.1.22.418), which Hinds in 1842 had labeled "*Murex*, sp.". It is a juvenile, measuring 23.2 mm in height, with an immature outer lip. The present specimen from off San Pablo, Ecuador (AMNH 213692, here illustrated, Figures 1-3, 7-9), is a larger (38.6 mm), more robust example of this species. The specimen identified as *?Ocenebra hamata* by Radwin and D'Attilio (1976, pl. 14, Fig. 2, from "off Peru") may represent another species. The shell is larger (66.8 mm in height), with the labial tooth situated medially, and it is colored a darker tan, tinged with brown.

No other specimens of this species were located in any of the leading U.S. museum collection nor in such private collections as that of Helen DuShane and Donald R. Shasky. The failure to find additional specimens in these collections attests to the apparent rarity of this species.

Systematics and Zoogeography

Pterorytis hamatus appears to be most closely related to the type species of *Pterorytis*, *P. umbrifer* (Conrad, 1832, p. 17, pl. 3, Fig. 1; Olsson and Harbison, 1953, pl. 35, Fig. 2; Emerson, 1959, Fig. 1), a species not uncommonly found in Pliocene deposits (Yorktown formation) of Virginia. Both species have a shell well-marked by a V-shaped indentation behind the acute labial tooth, as well as six foliated and spiniform varices. *Pterortyis hamatus* is, therefore, referable to *Pterorytis (sensu stricto)* and is the only known survivor of this Paciphile genus, which during the Neogene flourished in the tropical western Atlantic. The other extinct species of *Pterorytis* (see Olsson and Harbison, 1953, p. 252; Emerson, 1959, p. 4; Olsson and Petit, 1964, p. 549; Vokes, 1971, p. 141) have been referred to the subgenus *Neurarhytis* Olsson and Harbison (1953, p. 252) of which *P. fluviana* (Dall, 1903, p. 1633, pl. 60, Figs. 20, 21; Emerson, 1959, Fig. 2) is the type species. These taxa have heavier shells of moderate size, with four wide, terminally recurved, finely foliated varices per whorl and a weakly developed labial tooth without a prominent labial suture.

Pterorytis (Microrhytis) pecki (Emerson, 1959, p. 6, Fig. 4) from the Miocene of Veracruz, Mexico, may be referable to the genus *Ceratostoma* Herrmannsen, 1846, type species *C. nuttalli* (Conrad, 1837, p. 264, pl. 20, Fig. 22), as Vokes (1971, p. 125) has indicated. However, *P. pecki*, the type species of *Microrhytis* Emerson (1959), does possess a marginal indentation below the labial tooth, which is characteristic of *Pterorytis*, and has a shorter spire than typical species of *Ceratostoma*.

At the present time the geographical range of *Ceratostoma* is from Japan to northern Mexico (Cape San Lucas, Baja California Sur). Vokes (1964, p. 23; 1974, p. 8), however, reports in the Miocene of Silverdale, North Carolina (Trent marl of Richards, 1943) the presence of several amphi-North Pacific muricid genera, including *Ceratostoma*, that are no longer living in the western Atlantic. During the Neogene, the genus *Ceratostoma* is known to have been present in western Atlantic waters (North Carolina and possibly from Vera Cruz, Mexico), as well as in northeastern Pacific waters (Mio-Pliocene of California, Hall, 1959).

Acknowledgments

I am deeply indebted to Carol Skoglund for her kindness in calling to my attention and

donating her specimen to the AMNH. I thank John Taylor (BM(NH)) for the loan of Hinds' typological specimens and Anthony D'Attilio and Barbara Myers (SDNHM) for providing the line drawings of the radular dentition and the operculum and for preparing the radular mount, respectively. The following friends and colleagues assisted by searching their collections for specimens: Robert Robertson and Mary A. Garback (ANSP), Terrence M. Gosliner (CAS), James H. McLean (LACMNH), Ruth D. Turner and David H. Backus (MCZ at Harvard), Joseph Rosewater (NMNH), Anthony D'Attilio (SDMNH), Helen DuShane of Whittier, CA, and Donald R. Shasky of Redlands, CA. George and Wylda Stephens of Virginia Beach, VA, and Richard E. Petit of North Myrtle Beach, SC, generously provided fossil specimens of *Pterorytis*.

I also acknowledge the contributions of my AMNH colleagues: Walter E. Sage, III for technical services, and Peter Harries and Jeff Teitelbaum for the photography.

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CORBICULA FLUMINEA (BIVALVIA: CORBICULIDAE) IN THE STATE OF WASHINGTON IN 1937, AND IN UTAH IN 1978

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The exotic Asiatic bivalve, *Corbicula fluminea* (Müller, 1774) was first detected in North America at Nanaimo, Vancouver Island, British Columbia, in 1924 (Counts, 1981). The first report of *C. fluminea* in United States waters is that of Burch (1944) for specimens collected along the Columbia River at Knappton, Pacific County, Washington, in 1938. These are the earliest published records for *C. fluminea* in North America (McMahon, 1982, 1983; Counts, 1983).

A survey of the Corbiculidae collections held in the Department of Malacology of the Los Angeles County Museum of Natural History (LACM), conducted in June 1984, revealed a lot of *Corbicula fluminea* collected in April 1937 at Raymond, Pacific County, Washington (LACM 64359). The label accompanying the specimens states "Introduced from Japan. Immaculate Heart Collection. A. Burch". It does not specify a body of water as a collection locality. No details are available on either the Immaculate Heart Collection or the collector. The shape and color of the specimens is consistant with the "white form" described by Hillis and Patton (1982). A review of zoogeographic records for *C. fluminea* in Washington found that specimens were collected from the Willapa River at Raymond in 1971 (Counts, 1983) indicating that *C. fluminea* has survived in this region of Washington and suggesting that LACM 64359 may be representative of the population of origin.

Although LACM 64359 does not significantly alter the date of the introduction of *Corbicula fluminea* into United States waters, it is significant since it reinforces the hypothesis of a west coast introduction during the 1920's-1930's (Britton and Morton, 1979).

Acknowledgments: I would like to thank Mr. C. Clifton Coney and Dr. James H. McLean, Los Angeles County Museum of Natural History, for their assistance.

Utah

The Asiatic bivalve, *Corbicula fluminea* (Müller, 1774) has been reported from Utah only in general geographic terms (Cherry, *et al.*, 1980a, b; McMahon, 1982, 1983). These reports are in the nature of either lists of states where *C. fluminea* does or does not occur or United States maps with the State of Utah colored to indicate the presence of the species. No precise locality descriptions have been published for *C. fluminea* in Utah. A survey of 26 malacological collections held in museums throughout the United States, conducted between 1979 and 1982 failed to reveal any specimens collected in Utah (Counts, 1983).

A survey of the malacological collections of The Ohio State University Museum of Zoology (OSUM) conducted in June 1984 revealed two lots of *Corbicula fluminea* collected in Utah. Both lots (OSUM 52430 and OSUM 52431) were collected in the Sevier Reservoir (also known as Yuba Reservoir), 15.2 km northeast of Scipio, Juab County, Utah on 4 July 1978 by Richard L. Denton (Fig. 1). The shape and color of the specimens is consistant with the "white form" of Hillis and Patton (1982).

The Sevier River flows approximately 520 km from the Paunsaugunt Plateau of southwestern Utah north to Juab County where it then flows southwest to Sevier Lake. The river is located in the Great Basin and thus has no outlet to the oceans. Further, there is no connection with any other river in which *Corbicula fluminea* is known to exist. This indicates that *C. fluminea* was introduced into the Sevier River by means other than normal movements of the bivalves in the substratum. Zoogeographic studies of *C. fluminea* reveal the nearest known population is

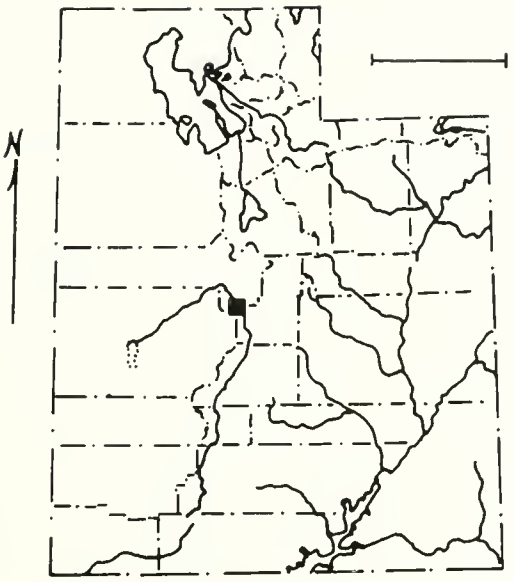

FIG. 1. Location of *Corbicula fluminea* in the Sevier River, Utah (Scale bar = 100 km).

located in Lake Meade of Arizona-California-Nevada (Counts, 1983). Whether the agent of introduction into the Sevier River was man or waterfowl is speculative at present.

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TROPICAL VERONICELLID, *LAEVICAULIS ALTE* (FÉRUSSAC), ESTABLISHED IN SOUTHERN TEXAS

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A number of tropical gastropods have been introduced into urban locations in Brownsville, Cameron County, Texas (Neck, 1976). Included are several veronicellid slugs, two of which were reported in an earlier communication (Neck, 1976). An additional species has been observed and was tentatively identified as *Pseudoveronicella liberiana* (Gould) (Neck, 1981). Recently, specimens from this population were sent to Lothar Forcart of Basel, Switzerland, and Jose Willibaldo Thome of Porto Alegre, Brazil, both of whom identified this species as *Laevicaulis alte* (Férussac, 1821).

Laevicaulis alte was most likely native to cen-

tral or eastern Africa (Forcart, 1953; *in litt.*). The type locality of this taxon is Pondicherry, India (Forcart, 1969). Human-mediated dispersal has allowed this species to establish populations in Madagascar, India, Indonesia, the Philippines, Australia and various island groups in Oceania (Forcart, 1953; Solem 1959, 1964).

This southern Texas record apparently represents the first establishment of *L. alte* in North America. Neither Hanna (1966) nor Dundee (1974) list *L. alte*, although this species has been established in Hawaii since the 1920's (as *Veronicella leydigi* (Simroth), in Cockerell, 1925). Summary papers by Baker (1925) and Thome (1975a, b) do not list *L. alte* for the Americas.

First observed in Brownsville in 1975, *L. alte* has subsequently become the most abundant veronicellid in urban residential yards. Later reports will discuss life history and interactions with other introduced veronicellids.

I thank Lothar Forcart and Jose Willibaldo Thome for their prompt identification of the slug.

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NEW RECORDS OF MARINE MOLLUSCA FROM KHOR ABDULLAH, IRAQ

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During the period of November 1982 to November 1983 a number of mollusks were obtained from the surface of sediments in Khor Abdullah in the northwest section of the Arabian Gulf.

The Khor Abdullah area is situated in a shallow sea and much of the coastline is bordered by mud and sandy silt (S. A. Darmoian, personal communication). The depth ranges between 5 and 12 meters. The new records include nine gastropods and sixteen bivalves:

1. *Euchelis asper* (Gmelin, 1791)
2. *Turritella terebra* (Linnaeus, 1758)
3. *Stellaria solaris* (Linnaeus, 1767)
4. *Tibia insulaechorab* (Röding, 1798)
5. *Strombus decorus persicus* (Swainson, 1821)
6. *Neverita didyma* (Röding, 1798)
7. *Ficus gracilis* (Sowerby, 1825)
8. *Rapana rapiformis* (Born, 1778)
9. *Inquistor griffithi* (Gray, 1834)
10. *Siphonaria basseinensis* (Melvill, 1893)
11. *Anadara antiquata* (Linnaeus, 1758)
12. *Striarca sculptilis* (Reeve, 1857)
13. *Pinna muricata* (Linnaeus, 1758)

14. *Pinctada radiata* (Leach, 1814)
15. *Pteria marmorata* (Reeve, 1857)
16. *Isogonomon legumen* (Gmelin, 1791)
17. *Malleus regulus* (Forskal, 1775)
18. *Placuna placenta* (Linnaeus, 1758)
19. *Trachycardium enode* (Sowerby, 1840)
20. *Gari occidens* (Gmelin, 1791)
21. *Bassina callophyla* (Philippi, 1836)
22. *Marcia hiantina* (Lamarck, 1818)
23. *Paphia gallus* (Gmelin, 1791)
24. *Periglypta reticulata* (Linnaeus, 1758)

The only previously published work on the area was by Ahmed (1975) which did not include the newly recorded species under consideration.

I wish to thank Dr. R. Tucker Abbott of American Malacologists Inc. for checking the identifications and reviewing the manuscript. I also wish to thank Dr. A. Al-Hashimi of the Kuwait Institute for Scientific Research, Dr. S. A. Darmonian and Dr. S. D. Salman of the Marine Science Centre, University of Basrah, for lending me their specimens.

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DISTRIBUTION OF THE SNAIL, *MELAMPUS BIDENTATUS*, AND THE MUSSEL, *GEUKENSIA DEMISSA*, ALONG THE PATAGUANSET ESTUARY (CONNECTICUT) IN RELATION TO SALINITY AND OTHER TIDAL MARSH INVERTEBRATES

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ABSTRACT

A survey was made of the tidal marshes along the Pataguanset Estuary in eastern Connecticut to determine the distributions of Melampus bidentatus *Say,* Geukensia demissa *Dillwyn and a few other invertebrates that are often associated with these mollusks. Salinity conditions at six stations located along the length of the estuary were examined, and an attempt was made to relate the distribution of these animals to salinity. The high marsh species,* Melampus bidentatus, Orchestia grillus *and* Philoscia vittata, *and the low marsh fiddler crab,* Uca minax, *were distributed from the head of the estuary to its mouth.* Geukensia demissa *and* Uca pugnax, *which also inhabit the low marsh, were absent at the head of the estuary where salinity sometimes falls to 0‰, but they were present in the marshes downstream. Toward the upstream extent of their distributions, the population densities of both* Melampus *and* Geukensia *sharply declined. The distributions of these mollusks were consistent with their known salinity tolerances, but it is not yet known to what extent salinity is a determining factor.*

Although the general community structure of tidal marshes is well-known (Teal, 1962; Day *et al,* 1973; Nixon and Oviatt, 1973; Subrahmanyam *et al,* 1976; Fell *et al,* 1982), relatively little information exists concerning the distribution of tidal marsh invertebrates in relation to salinity. Tidal marshes frequently extend far up estuaries, and consequently salinity may be an important factor influencing the occurrence of animals within such marshes. Most of the few

previous studies on the relationship between salinity and the distribution of tidal marsh invertebrates have dealt with only a single or two closely related species (see Daiber, 1977 and 1982 for reviews). Therefore almost no information is available on how salinity may influence community structure as a whole.

A number of studies of tidal marsh mollusks have focused on the high marsh snail, *Melampus bidentatus* Say, or the low marsh mussel, *Geukensia* (formerly in *Modiolus*) *demissa* Dillwyn. In general surveys of the Delaware Bay and Chesapeake Bay areas, *Melampus* (Wass *et al*, 1972; Leathem and Maurer, 1975; Parker, 1976) and *Geukensia* (Wass *et al*, 1972; Maurer *et al*, 1974) were found to have an upper meso-and polyhaline distribution. Parker (1976) showed that although *Melampus* occurred in regions which exhibit a wide range of salinity, its population density was low where salinity was less than about 10‰. Kerwin (1972) investigated the distribution of *Melampus* along an estuary in Virginia; but this snail did not occur in large numbers at any of the sampling stations, suggesting that factors other than salinity may be of primary importance in limiting its abundance within that system.

The purpose of the current study was twofold: 1) to examine the salinity conditions at six stations along the length of the Pataguanset Estuary in eastern Connecticut, and 2) to describe the occurrence of *Melampus bidentatus* and *Geukensia demissa* in relation to salinity and to the distribution of several other tidal marsh invertebrates.

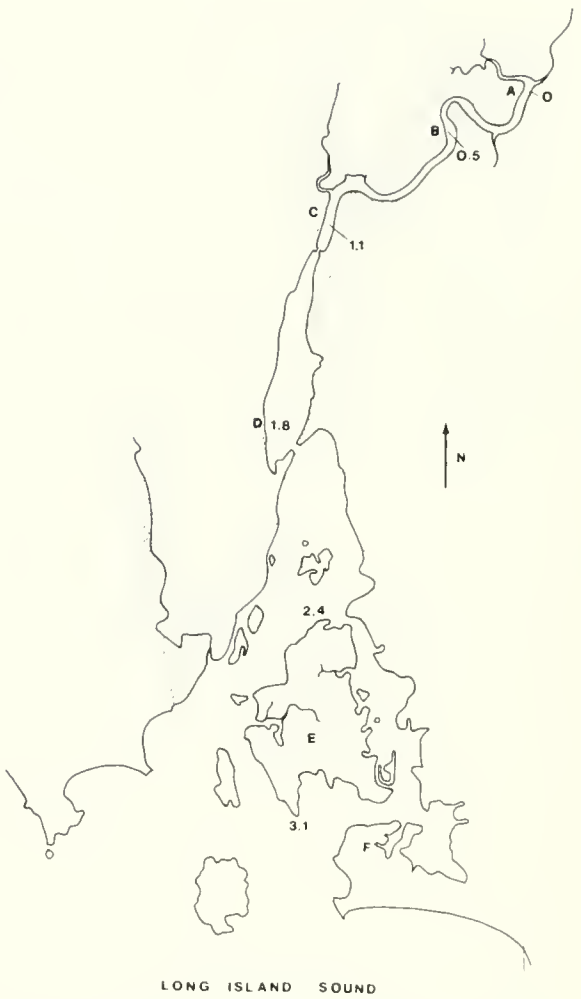

FIG. 1. The Pataguanset Estuary. Tidal marshes are indicated by stippling. Salinity sampling stations are designated by their distance in kilometers from the head of the estuary. Invertebrate sampling stations are shown by letters (A to F). E is Watts Island.

Study Site; Methods

The Pataguanset Estuary is located in eastern Connecticut and opens into Long Island Sound to the west of Niantic Bay from which it is separated by Black Point. The estuary, which is about 3.5 km long, is bordered by tidal marshes and on the south by the large tidal marsh Watts Island (Fig. 1). In most places the depth of the estuary ranges from about 1 to 2 m at high tide. Extensive beds of widgeon grass, *Ruppia maritima*, cover the tidal flats of the lower estuary in the region extending from about 1 to 3 km from the head. Water temperatures along the estuary reach about 25°C during the summer and fall below 0°C during the middle of the winter when much of the estuary may be covered by ice.

Six stations were established along the estuary for studying salinity. These were located at 0.5 to 0.7 km intervals from the head of the estuary to a region near its mouth (Fig. 1). During a period extending from late spring through early fall of 1981 and June through August of 1982, surface and bottom salinities at high water of spring tides were determined every 2 weeks. Twice, once in late June and again in late July 1981, salinities were recorded at about hourly intervals covering half of a tidal cycle from low to high tide. Salinities were

measured in the field with a Goldberg refractometer (American Optical Co.). A few determinations of soil water salinities in the high marsh were made after squeezing the water from samples of peat and filtering the water through Whatman no. 1 filter paper.

Previous studies on the distribution and abundance of *Melampus bidentatus* on Watts Island in the Pataguanset Estuary and on other Connecticut tidal marshes have shown that this snail occurs at high densities in areas of the high marsh covered by *Spartina patens*, stunted *Spartina alterniflora* and *Juncus gerardi* (Fell *et al*, 1982 and unpublished observations). For this study it was decided to sample *Melampus* in *S. patens* and *Juncus* because of the abundance of one or both of these plants in marshes along the entire estuary. During the summer of 1981 *Melampus* was studied at six stations (Fig. 1). The population density of this snail was determined using a 50 cm square wooden frame, 9 cm high, which was tossed onto the marsh in areas of chosen plant cover and at distances of about 2 to 50 m from the water. The vegetation within the frame was clipped at the surface of the peat and all of the snails were collected and enumerated. At the same time the presence of two other high marsh invertebrates, *Philoscia vittata* (isopod) and *Orchestia grillus* (amphipod), was noted. The number of quadrats examined at each station is presented in Table 2.

The abundance of *Melampus*, *Philoscia* and *Orchestia* at the three stations along the upper estuary was studied in greater detail during the summer of 1982. For this purpose 5 transects running perpendicular to the river bank and situated 15 m apart were set out at each site. Each transect was 25 m long, beginning at the lower edge of the high marsh; and six 50 cm square quadrats placed 5 m apart were examined along each transect. Sampling was done during June, July and August at all three stations. Transect sampling was used to eliminate bias in the selection of sampling sites.

The population size of *Geukensia demissa* was estimated at each of 5 stations during 1981 by counting the number of animals within five 5.5 m transects which extended along the banks of the estuary, except at station E (Watts Island) where the transects were located along a tidal creek. The width of the transects (*ca* 1 to 2 m) extended from the edge of the water at low tide to the upper edge of the tall *Spartina alterniflora* zone. Sampling was done along sections of both banks to assure a representative sample. In addition, the relative abundance of the fiddler crabs, *Uca minax* and *Uca pugnax*, was determined in these areas by digging from 50 to about 70 crabs from their burrows at low tide.

Salinities

There is considerable seasonal variation in salinity at stations in the upper estuary. For example, the surface salinity at the head of the estuary (St. 0) during high water of spring tides ranged from 0‰ during early June to more than 20‰ during late summer of 1981 (Fig. 2). However, at the head of the estuary the surface salinity may drop dramatically whenever there are heavy rains. In mid-September of 1981 the surface salinity at station 0 during high water of a spring tide was only 2‰ due to fresh water drainage. The range in surface salinities during high water of spring tides narrowed toward the mouth of the estuary, and at 1.8 km downstream the range was only 24 to 32‰ over the period of observation. During the summer of 1982, surface salinities at the 3 stations of the upper estuary during high water of spring tides exhibited patterns similar to those of 1981, but they were often 5 to 10‰ lower for any particular time.

Salinities recorded at different times during the tidal cycle also exhibited substantial changes

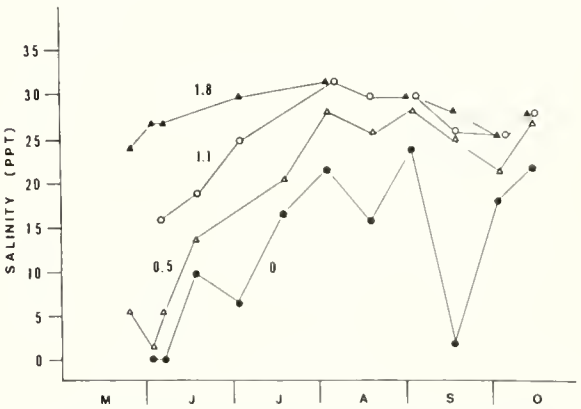

FIG. 2. Surface salinities at four stations along the upper Pataguanset Estuary during high water of spring tides in 1981. The stations are designated by their distance in kilometers from the head of the estuary.

at stations in the middle and upper regions of the estuary (Fig. 3). At the station 1.1 km from the head of the estuary, the surface salinity ranged from 3‰ at low water to 20‰ at high water during neap tides in late June and late July of 1981. As would be expected, the surface salinities at the head of the estuary were frequently much greater during high water of spring tides than during the same period of neap tides (Figs. 3 and 4). Often the salinity at the surface and that at the bottom were identical or very similar; however, occasionally stratification was noted at the stations of the upper estuary. The difference between surface and bottom salinities at any given station usually did not exceed 10‰ and was greatest during high tide. However, when a perigee spring tide occurred during a period of heavy rain (16 Sept. 1981), the surface salinity at the head of the estuary was 2‰ at high water while the bottom salinity was 25‰.

On two occasions the salinity of the water actually flooding the high marsh of the upper estuary was measured and found to be about the same as the surface salinity in the channel. However, the salinity of the water just above the peat was somewhat different. For example, once when station A was flooded to a depth of about 20 cm the salinity at the surface was 2‰, as it also was in the channel, but close to the peat the salinity was 5 to 7‰.

In late June and again in late July of 1981 the salinity of the soil water of the high marsh was measured at stations in the upper estuary during low tide. The soil water had a salinity of 7 to 16‰ near the head of the estuary and exhibited progressively high salinities at stations toward the mouth (Table 1).

Animal Distribution

Melampus bidentatus was found at all stations along the estuary (Table 2). However, it was less abundant in the brackish marshes near the head of the estuary than in the marshes toward the mouth. Another pulmonate snail, *Succinea wilsoni* Lea, which is typically found in fresh-

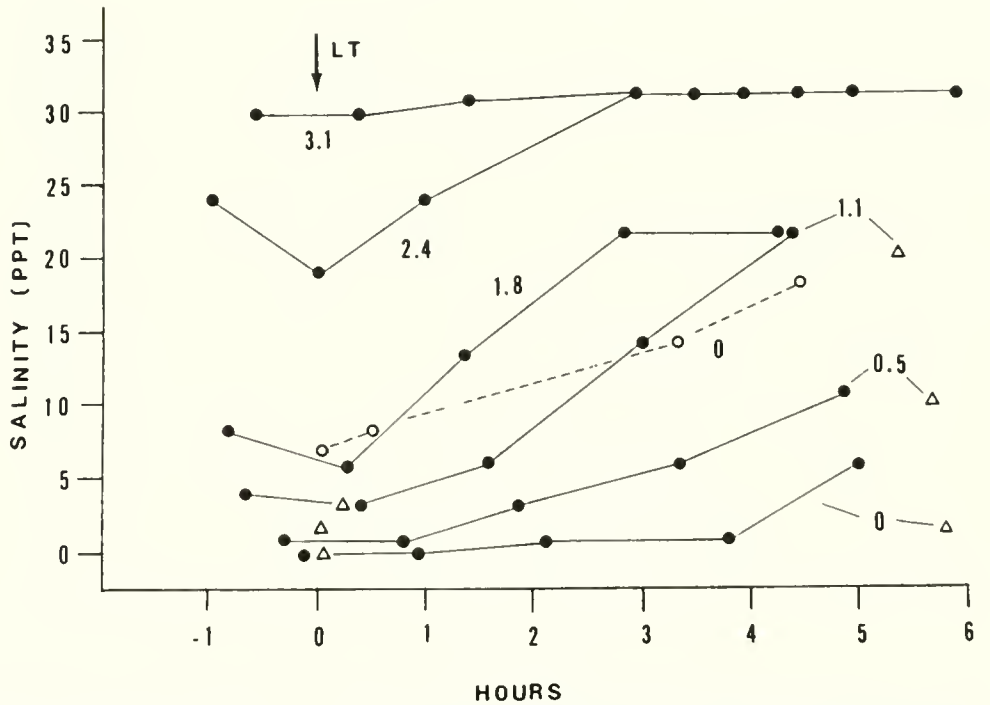

FIG. 3. Surface salinities at six stations along the Pataguanset Estuary during the flooding phase of the tidal cycle. The stations are designated by their distance in kilometers from the head of the estuary. Solid circles joined by continuous lines show salinities during part of a neap tidal cycle on 22 July 1981; open triangles indicate the low tide and high tide values during a neap tide on 23 June 1981; and open circles joined by broken lines show salinities at station 0 on 5 August 1981. LT = low tide.

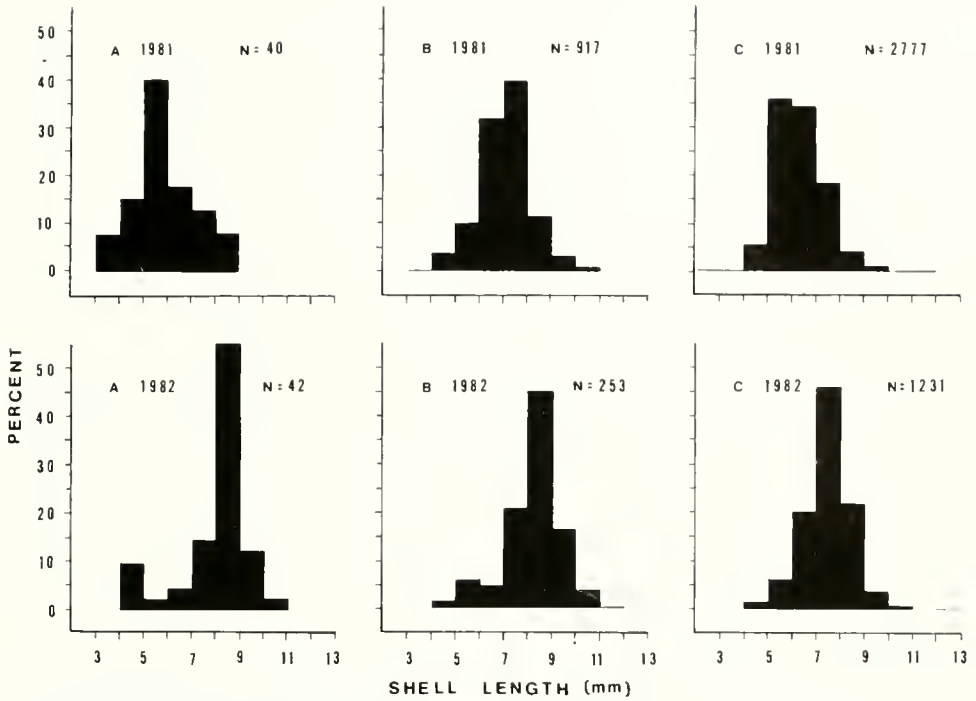

FIG. 4. Size frequency distribution of *Melampus bidentatus* at 3 stations along the upper Pataguanset Estuary during 1981 and 1982.

TABLE 1. Soil water salinities at stations in the upper Pataguanset Estuary during periods of neap tides.

Station	Salinity (‰) - 1981 6/23	7/22
A	7-11	11-16
B	13-16	20-25
C	---	32

water marshes, occurred together with *Melampus* at stations A and B. The vegetation in the higher regions of these brackish marshes consisted of *Juncus gerardi* and *Spartina patens* mixed with *Solidago sempervirens*, *Potentilla anserina*, *Gerardia maritima*, *Panicum virgatum* and other species. Downstream the numbers of *Melampus* increased until at 1 km or more from the head high densities of this snail were found in relatively pure stands of *Juncus gerardi* and of *Spartina patens*. Two invertebrates that are normally associated with *Melampus* in salt water marshes, *Philoscia vittata* and *Orchestia grillus*, (Fell *et al*, 1982) were also distributed all along the Pataguanset Estuary, including the brackish marshes at its head (Table 2).

Although the surveys of 1981 and 1982 were in agreement in showing a progressive decline in the population density of *Melampus* in the marshes of the upper estuary, the density of this snail at particular stations was much lower during the second summer (Table 3). In addition, during 1982 there was also a marked reduction in the proportion of smaller individuals (Fig. 4). It is not known whether these changes were related to the lower salinities occurring during 1982 or to other factors such as high winter mortality.

Geukensia demissa did not occur at the head of the estuary. Only a few small mussels were observed 0.5 km below this point, but at 1 km or more from the head these animals were moderately abundant (Table 3). Fiddler crabs often occur together with *Geukensia* in the low marsh. Two species of fiddler crab, *Uca minax* and *Uca pugnax*, were found; and one or both species were present at stations all along the Pataguanset Estuary. Only *Uca minax* occurred at the head of the estuary and this species was the dominant fiddler crab at the station 0.5 km downstream. However, at all of the lower stations *Uca pugnax* predominated. The distribution of this fiddler crab was essentially the same as that of *Geukensia*.

TABLE 2. Abundance, no. per 0.25m² (mean ± S.D., range), of high marsh invertebrates along the Pataguanset Estuary in Connecticut. N = no. of quadrats examined.

	Melampus bidentatus						*Philoscia vittata*		*Orchestia grillus*	
Station	N	1980	N	1981	N	1982	N	1982	N	1982
A			10	4±5,0-15	30	1±5,0-24	30	3±3,0-8	30	3±3,0-10
B			20	46±31,4-134	30	8±10,0-43	30	7±11,0-56	30	5±5,0-24
C			15	184±99,14-336	30	41±35,0-146	30	6±6,0-31	30	4.5±4,0-16
D			5	222±53,163-284						
E	36	92±81,0-312	15	79±75,6-306						
F			14	112±83,2-263						

TABLE 3. Distribution of low marsh invertebrates along the Pataguanset Estuary in Connecticut during the summer of 1981 (number of *Geukensia* per 5×5.5m transects).

Station	*Geukensia demissa*	*Uca pugnax: Uca minax*
A	0	0:64
B	3	9:45
C	196	43:7
D	410	54:1
E	143	65:4

Discussion

Geukensia demissa was moderately abundant in the lower portions of the Pataguanset Estuary where the salinity of the water at high tide probably only rarely drops much below 10‰. On the other hand, it was absent from the marsh at the head of the estuary and was present in only small numbers 0.5 km downstream. At these stations the surface salinities at high tide were sometimes as low as 0 to 2‰. *Uca pugnax* had a similar distribution, but *Uca minax* was abundant at stations along the banks of the upper estuary. *Geukensia* can survive and remain active at salinities as low as 8‰, but evidently is unable to tolerate prolonged submergence by water of salinities below about 5‰ (Wells, 1961; Lent, 1969; Pierce, 1970; Maurer *et al*, 1974). Similarly, Teal (1958) has shown that *Uca pugnax* is less tolerant of low salinity than is *Uca minax*, succumbing within a few days if submerged in water with a salinity of 7‰ or lower (LD_{50} = 1.5 days at 0‰ and 3 days at 7‰). Furthermore, when given a choice between fresh water and 30‰ sea water, *Uca pugnax* usually chose sea water while *Uca minax* usually chose fresh water. The predominance of *Uca minax* in regions of low salinity and of *Uca pugnax* in regions of high salinity has been observed in a number of marsh systems (Teal, 1958; Kerwin, 1971; Miller and Maurer, 1973). Competition between these 2 species of fiddler crabs, as well as other factors, undoubtedly also influence their distribution (Teal, 1958; Miller and Maurer, 1973; Daiber, 1977). The fact that *Geukensia demissa* and *Uca pugnax* have similar salinity tolerances and exhibit essentially the same distribution along the estuary lends strength to the hypothesis that salinity may be an important factor determining their distribution within this system.

Melampus bidentatus was found all along the Pataguanset Estuary, as were *Orchestia grillus* and *Philoscia vittata*. The high marsh is basically a terrestrial environment most of the time, but it is regularly flooded by spring tides. Consequently, the salinity of the estuarine waters could be expected to exert less of an influence on the distribution of animals inhabiting this region than on those of the low marsh which is inundated more often and for longer periods. On the other hand, the density of *Melampus* was lower in the brackish marshes of the upper estuary and this may be related, at least in part, to the lower salinity of the soil water and/or more probably of the waters of inundation. Not only may low salinity have a direct influence on the snails but it may also act indirectly through its effects on the vegetation which is different in the brackish marsh. The observations of Parker (1976) further support this suggestion. In a study of 12 sites along the New Jersey and Delaware sides of Delaware Bay and 4 stations along the Broadkill River in Delaware, he also found that *Melampus* occurs in brackish marshes but that its population density is low where the salinity is less than about 10‰. Along a tributary of the York River in Virginia, *Melampus* was absent from marshes in regions where the mean surface salinity was below 4‰

and was present in only small numbers in marshes located toward the mouth (Kerwin, 1971 and 1972). In this system it appears that other factors besides salinity may be of major importance in limiting snail density.

Melampus adults are remarkably tolerant of submergence in water ranging in salinity from full strength sea water to fresh water. They were found to survive total submergence in fresh water for a least one day at 20°C and for at least 8 days at 10°C (Price, 1980; McMahon and Russell-Hunter, 1981). *Melampus* possesses a planktonic larva (Russell-Hunter, Apley and Hunter, 1972) which is also tolerant of low salinities (Parker, 1976). The larvae are highly active at salinities ranging from 15 to 40‰, slightly less active at 10‰ and much less active at 5‰. About 90% of 2-day-old larvae were observed to survive for at least 10 hrs. in salinities ranging from 2.5 to 40‰, but none survived that long in fresh water (Parker, 1976).

Although the distributions of *Melampus bidentatus* and *Geukensia demissa* along the Pataguanset Estuary are consistent with the salinity tolerances of these animals determined by laboratory experiments, it is not yet known whether salinity is, in fact, a major factor determining the distribution and abundance of these animals. Among other factors that may be important are predation, composition of the substratum and flooding regime. Future studies should focus on more precisely defining the conditions which actually exist in various regions of the marsh system and on how these conditions affect all stages of the life history of the animals which live there. This will require that field measurements be made at frequent intervals, if not continuously, throughout the year and that field studies be accompanied by extensive laboratory experiments. In most laboratory studies, the effects of continuous exposure to a particular set of conditions are examined. However, in the marsh flooding is periodic, and therefore it would be desirable to look at the effects of submersion by water of different salinities under regimes comparable to those that would be experienced by animals in the field. Until such comprehensive studies have been carried out, it will not be possible to make really meaningful statements concerning the causative factors which result in the observed distributional patterns.

Acknowledgments

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TWO NEW SPECIES OF *LYRIA* FROM THE WESTERN ATLANTIC (GASTROPODA: VOLUTIDAE)

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ABSTRACT

Lyria leonardi *n. sp. and* Lyria russjenseni *n. sp. are described from recently collected specimens obtained in moderate depths off southwestern Puerto Rico. The former species is also known from the Gulf of Triste, Venezuela, and off Grenada in the Lesser Antilles on the basis of fragmental specimens. Both taxa are compared with extant and extinct species of* Lyria *occurring in the Caribbean region.*

The volutid genus *Lyria* (*sensu stricto*) is represented in the Tertiary of the western Atlantic region by eight extinct species (Hoerle and Vokes, 1978) and by six extant species, including the two new taxa described herein (Weaver and duPont, 1970; Bayer, 1971). I take pleasure in naming the new species in honor of Fred L. Leonard and Russell H. Jensen, who kindly called my attention to specimens of these taxa and generously donated their respective specimens to the American Museum of Natural History (AMNH) type collection.

The previously known western Atlantic Recent species that have been referred to the nominate subgenus are:

1. *Lyria beauii* (Fischer and Bernardi, 1857), pl. 9, figs. 1, 2; Dance, 1969, pl. 16, fig. c; Weaver and duPont, 1970, pl. 4, figs. I, J; Pointier, 1981, pl. 1, figs. 1-4; and Abbott and Dance, 1982, p. 213. Type locality: Marie-Galante, Lesser Antilles. Known only from a few specimens taken in the Lesser Antilles, most recently from off Guadeloupe Island.

2. *Lyria archeri* (Angas, 1865), p. 55, pl. 2, figs. 4, 5; Weaver and duPont, 1970, pl. 7, figs. G, H; Abbott, 1974, p. 245, fig. 2675 (not *L. beauii*); Pointier, 1981, pl. 2, figs. 6-14; Abbott and Dance, 1982, p. 213. Type locality: Montserrat, Lesser Antilles, recently obtained off Martinique (AMNH coll. 183213). R. T. Abbott reports (*in lit.*) that Lesley Sutty collected specimens in Guadeloupe in 1969. Dall (1907, p. 351) referred this species to the genus-group taxon *Enaeta* H. & A. Adams (1853, vol. 1, p. 167) in the mistaken belief that the outer lip had similar labial dentition. In *Enaeta*, a blunt, tooth-like projection occurs near the midpoint of the outer lip near the margin of the labrum, (Hoerle and Vokes, 1978, p. 115). In *Lyria archeri*, the edge of the labrum is weakly serrated and pustule-like denticles form at the marginal base of some of the serrations inside the outer lip. These

"teeth" are prominent in the holotype (Weaver and duPont, 1970, pl. 7, fig. H). As Tryon (1882, p. 104) pointed out, however, the shell of *Lyria archeri* somewhat resembles that of the Indo-Pacific *Lyria* (*L.*) *mitraeformis* (Lamarck, 1811). This species apparently is not closely allied to the other living *Lyria* in the Caribbean region.

3. *Lyria vegai* Clench and Turner, 1967, fig. 1; Weaver and duPont, 1970, pl. 6, figs. F, G; Abbott, 1974, p. 245, fig. 2676; Pointier, 1981, pl. 1, fig. 5; Abbott and Dance, 1982, p. 214 (holotype illus.). Type locality: "Cabo Rojo, Prov. Pedernales, República Dominicana, Hispaniola", in a fish trap. Known only from the holotype.

4. *Lyria cordis* Bayer, 1971, figs. 58 (shell), 59 (living animal), 60 (radula), 61 (a, gross anatomy; b, operculum); Abbott, 1972, p. 139 (living animal), Abbott, 1974, p. 245, fig. 2677; Pointier, 1981, pl. 1, fig. 6; Abbott and Dance, 1982, p. 214 (holotype). Type locality: "Caribbean Sea, 20 miles ESE of Sto. Domingo, Island of Hispaniola, 18° 21.0′ N, 69° 14.3′ W, depth 174 m." Known only from 2 specimens from the type locality. This is the type species of the genus-group taxon, *Cordilyria* Bayer (1971, p. 204). Notwithstanding the fact that axial sculpture occurs only on the first and second post nuclear whorls in the type species (*L. cordis*) as well as in *Lyria vegai*, and axial costae are prominent on the body whorl and the earlier whorls of *Lyria beauii*, *L. russjenseni* n. sp. and *L. leonardi* n. sp., these five species appear to be more closely related to each other than to *Lyria archeri*. They form a species complex for which the subgenus *Cordilyria* is available, if recognition is subsequently deemed warranted on the basis of anatomical differences with the Indo-Pacific *Lyria*. For the present, *Lyria archeri* seems best retained in *Lyria* (*sensu stricto*).

The New World representatives of the *Cordilyria* species complex occur in moderately deep water in the Caribbean Sea and are rarely found in collections. All the specimens I have examined of the two species described here were dead-collected. Most appear to have been occupied by hermit crabs, which would account for the presence of these shells in baited fish traps. The shells possess one or more octopus drill holes, suggesting that the specimens were the victims of octopod predation.

Family **Volutidae** Rafinesque, 1815
Subfamily **Lyriinae** Pilsbry and Olsson, 1954
Genus ***Lyria*** Gray, 1847

Lyria Gray, 1847, p. 141; type species by original designation: *Voluta nucleus* Lamarck, 1811, Recent, Indo-Pacific.

Lyria leonardi *new species*

Figures 1 to 6

Lyria beauii Fischer and Bernardi, Dall, 1907, p. 351, fragmental specimen, National Museum of Natural History (NMNH) 87718, near Grenada, in 133.5 m. Not *Lyria beauii* (Fischer and Bernardi, 1857).

Lyria cf. *limata* Hoerle and Vokes, Petuch, 1981, p. 331, figs. 75, 76, Golfo de Triste, Venezuela, in 16 m. Not *Lyria (L.) limata* Hoerle and Vokes, 1978, p. 111, pl. 1, figs. 4, 5, Chipola Formation, Florida, Miocene.

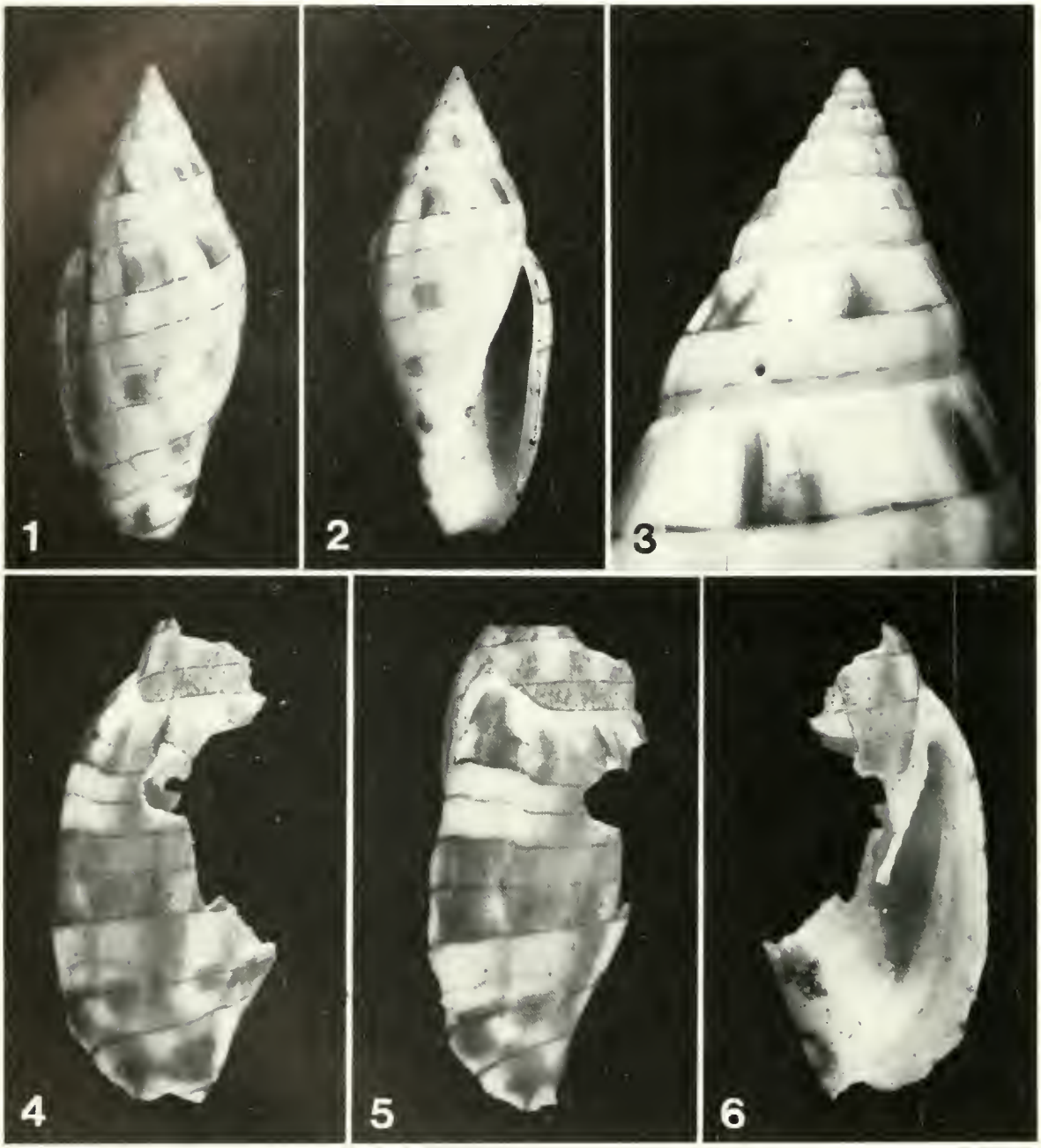
Diagnosis: Ovately fusiform shell, large for genus, attaining 100+(?) mm in length, of 8½ whorls; axial sculpture of 11 to 14 weakly folded ribs; color tannish white; spirally banded by irregular squarish blocks of brown below the suture and with 3 similar spiral bands on the body whorl; spirally threaded by 6 to 7 brown, strongly penciled lines on the body whorl, with 1 to 3 similar spiral lines on the earlier post nuclear whorls; aperture whitish with yellowish buff submarginal callus within the outer lip.

Description: Shell ovately fusiform; 2½ smooth nuclear whorls; 6 post nuclear whorls; first 3 post nuclear whorls with 14 well-defined axial costae (see Fig. 3); remaining post nuclear whorls with 11 loosely formed axial ribs; suture weakly defined; aperture elliptical, more than ½ the height of the shell; outer lip lacking marginal barbs, thickened internally by a submarginal lenticular callus; columella with 3 prominent adapical plications and 9 thread-like lirations, with the most adapically placed lira best developed; siphonal fasciole weak, anal sulcus shallow; operculum and radula unknown. Color, see diagnosis.

Type locality: off Cabo Rojo, Puerto Rico, trawled in 500± m., ex-E. Flynn Ford coll., ex-Fred L. Leonard coll., 1981.

Holotype: AMNH no. 213575, from the type locality; height = 52 mm, width = 21.2 mm. Here illustrated, Figs. 1, 2 and 3.

Paratype: NMNH no. 820640, R/V *John*



FIGS. 1-6. ***Lyria leonardi*** *new species.* **1-3,** Holotype, AMNH no. 213575; **4-6,** Paratype, NMNH no. 820640. **1** and **2** approximately × 1⅓; **3,** early whorls greatly enlarged; **4-6,** × 1.

Elliott Pillsbury station P-758 (11° 42.4′ N., 60° 40′ W), in 16 m., Golfo de Triste, Venezuela (see Petuch, 1981, p. 331, figs. 75-76); fragment lacking pre-body whorls, height = 72.00 mm. Here illustrated, Figs. 4-6.

Referred specimen: NMNH no. 87718, U.S. Fish Commission station 2120, in 133.5 m, near Grenada, Lesser Antilles (see Dall, 1907, p. 351); fragment lacking much of the body whorl, height = 29.3 mm.

Remarks: The color pattern approaches that of *L. limata* Hoerle and Vokes (1978, pl. 1, figs. 5a, 5b), but this smaller, more slender Miocene species has better developed costae, stronger and fewer columellar lirations, and possesses barbs on the outer lip.

Lyria russjenseni *new species*

Figures 7 to 15

Diagnosis: Shell narrowly fusiform, 8½ whorls, medium size for genus, attaining 70+ mm in height; axial sculpture of 12 to 13 irregularly formed ribs; color buff-cream with small v-markings, spirally banded by broken blotches of irregular brown squares below the suture, midway and anteriorly on the body whorl; bands interrupted by zigzag patterns, especially at base of the body whorl; outer lip ringed within by a yellowish buff, submarginal callus; aperture white.

Description: Shell slender, fusiform; 2½ smooth nuclear whorls; 6 post nuclear whorls; axial costae 12 to 13 per whorl, weakly developed on 1st and 2nd post nuclear whorls (see Fig. 15); obsolete on 3rd and 4th whorls; prominent on penultimate whorl and body whorl; suture distinct, weakly channeled; aperture narrowly elongate, about ½ the height of the shell; interior of outer lip thickened submarginally by a lenticular callus in mature specimens, lacking marginal barbs; columella with 3 prominent adapical plications and 12 to 17 weak lirations extending into the aperture, terminating in a more prominent lira at the adapical end in mature specimens. Siphonal fasciole weak; anal sulcus narrow and shallow; operculum and radula unknown. Color, see diagnosis.

Type locality: off La Paguera, Puerto Rico, taken in a lobster pot by fisherman, 1978, ex-Miguel Carlo, ex-Russell Jensen coll.

Holotype: AMNH no. 213576, from the type locality; height = 65.5 mm, width = 26.2 mm. Here illustrated, Figs. 7, 8.

Paratype A: off Cabo Rojo, Puerto Rico, in a fish trap, in approximately 244 m., ex-Miguel Carlo, 1983, Harry G. Lee coll.; height = 71.5 mm, width = 28.8 mm. Here illustrated, Figs. 9, 10, and 15.

Paratype B: off Cabo Rojo, Puerto Rico, in a fish trap set 8 to 10 miles off shore in approximately 300 m., mid-1979, ex-Miguel Carlo, Gregory Curry Sr. coll.; height = 39.4 mm, width = 17.2 mm.

Paratype C: AMNH no. 213574, same locality as paratype B, ex-Miguel Carlo, 1979, ex-Richard Goldberg coll.; height = 26.8 mm, width = 13.4 mm. Juvenile specimen, here illustrated, Figs. 13, 14.

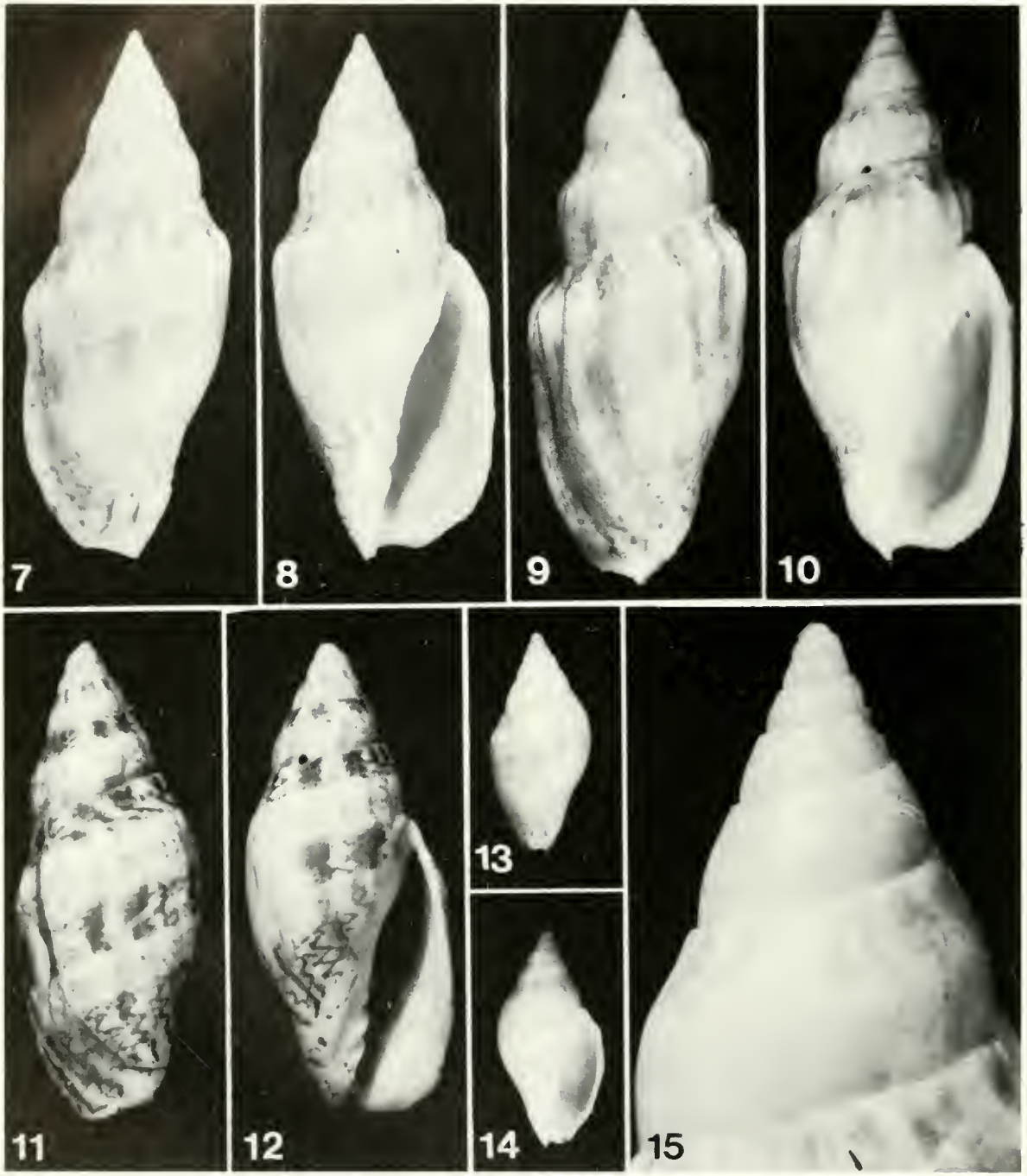
Paratype D: same locality as paratype B, ex-Miguel Carlo; Gregory Curry, Sr. coll.; height = 57.7 mm (apex incomplete), width = 25.4 mm. Here illustrated, Figs. 11, 12.

Paratype E: off Mayaquez, Puerto Rico, in a fish trap, set in 274 mm; ex-Miguel Carlo, 1982, Michael Cahill coll.; height = 56 mm, width = 24 mm.

Remarks: This species resembles *L. beauii* (Fischer and Bernardi, 1857) in shell morphology, but it differs in having less extended axial ribs on the body whorl, and a distinctive color pattern. In *Lyria leonardi* n. sp. the axial ribs adjoin the suture, whereas in the present species and *L. beauii* the ribs are poorly developed at the suture in mature specimens (Figs. 7-10).

Acknowledgments

In addition to Russell H. Jensen and Fred L. Leonard, I am indebted to a number of people for valuable contributions to this study. The following generously provided specimens on loan and/or contributed pertinent information: Kirk Anders, Michael Cahill, Miguel Carlo, Gregory Curry, Sr., C. John Finlay, Mary S. Ford, Richard Goldberg, Thomas Honker, Harry G. Lee, Edward J. Petuch, Joseph Rosewater, John K. Tucker, and Thomas R. Waller. My AMNH colleagues, Walter Sage, III, Peter J. Harries, and Stephanie Crooms kindly provided technical assistance, photography, and the word processing, respectively.



FIGS. 7-15. ***Lyria russjenseni*** *new species.* **7** and **8**, Holotype, AMNH no. 213576; **9**, **10**, **15**, Paratype A, H. G. Lee coll.; **11** and **12**, Paratype D, G. Curry, Sr. coll.; **13** and **14**, Paratype C. AMNH no. 213574. **7-14** approximately × 1⅓; **15**, early whorls greatly enlarged.

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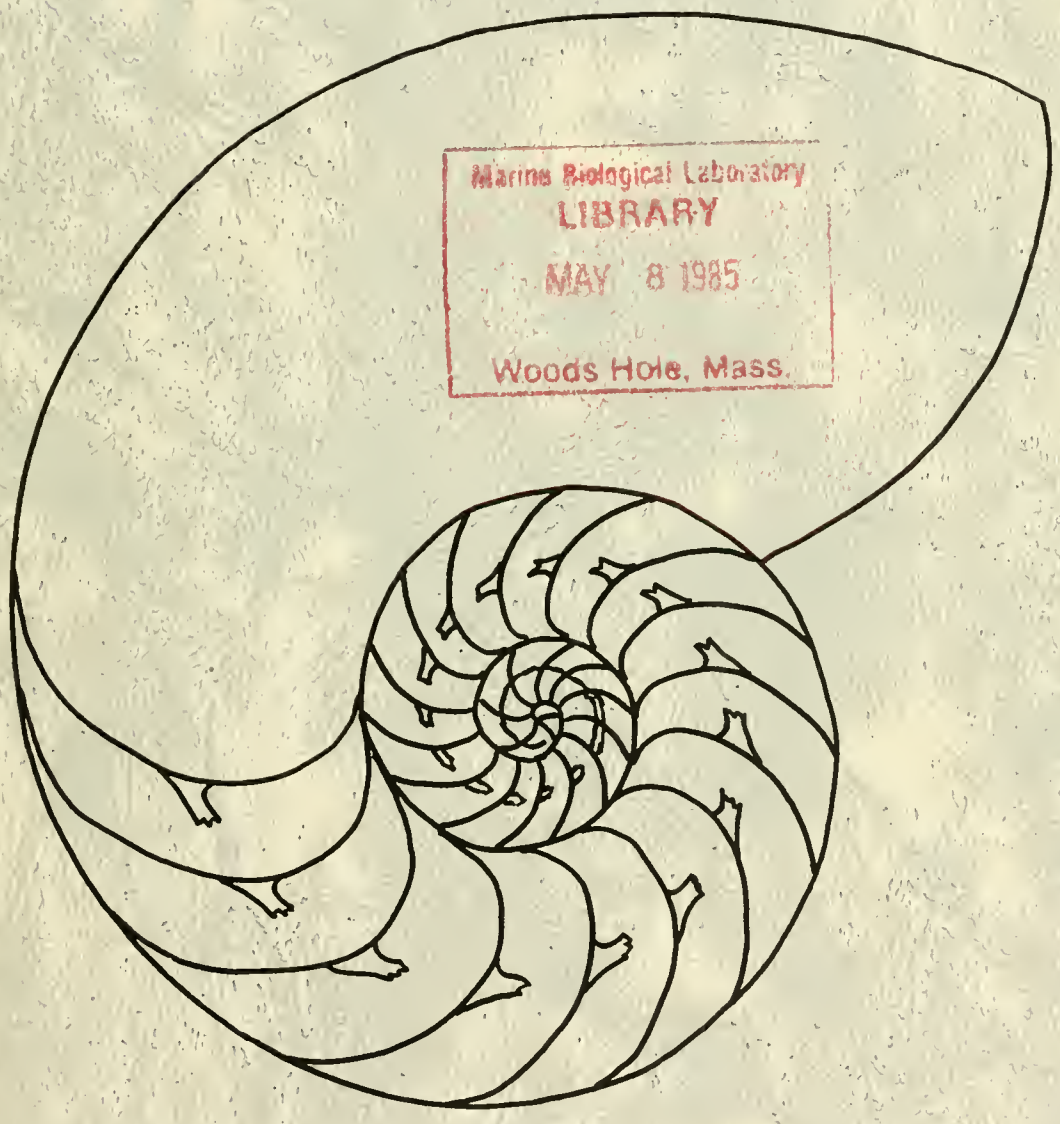

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(signed) R. Tucker Abbott, Editor

Faye B. Howard, 1907 - 1984

The Santa Barbara Museum of Natural History recently lost one of the driving forces behind the development of malacology in the Department of Invertebrate Zoology. Della Faye Ballou was born at home in Crumpler, North Carolina on February 15, 1907. At the age of ten her family moved to California. She attended Fullerton City College and the University of California, Berkeley where she was introduced to shells by her neighbor, John Jones. Beginning in 1932 until shortly before her death, Faye engaged in private research in conchology. In 1961 she was appointed as a Research Associate in Conchology at the Museum. From 1961 to 1968 she personally funded the position of Assistant in Conchology at the Museum. During the same period Faye organized, financed and led six major expeditions to West Mexico to study and collect mollusks. With the impetus of Faye's enthusiasm and support, the Santa Barbara Malacological Society was founded in 1962. She served on the Editorial Board of the Society's publication, the *Tabulata*, from 1967 to 1974. Faye was a member of the Conchological Club of Southern California for 54 years and was also a member of the Hawaiian Malacological Society. She authored a total of 22 publications on mollusks and famous malacologists. She described two new species of marine gastropods, and had four new species and one new subspecies named in her honor. She died December 14, 1984. Faye's dream of establishing a major center for the study of mollusks in Santa Barbara will become a reality, supported by her large collection and a bequest which she leaves to the museum. This legacy will forever preserve her memory but will never fill the void she leaves behind.

–F. G. Hochberg

THE NAUTILUS – ITS 99th YEAR
(an editorial)

The Nautilus had its beginnings in Philadelphia on July 1, 1886. That means we shall be celebrating our 100th anniversary next year, in 1986. We began as *The Conchologist's Exchange*, with W. D. Averell as editor. When Henry A. Pilsbry took over as the chief editor in 1889, the name was changed at the third volume to *The Nautilus*. Since then, in the span of 96 years, there have been only three chief editors–Henry A. Pilsbry, H. Burrington Baker and myself.

It is time for an editorial. Its purpose is to invite our friends and subscribers, both professional malacologists and private amateur collectors, to participate in our celebration of 100 years of service to the malacological community. We will briefly review the history of the journal, but our main theme will be a memorial tribute to the late William J. Clench and to his former student, the late Joseph Rosewater. The 100th volume will largely consist of scientific articles on mollusks, many by Bill Clench's students, that acknowledge his help or that may name a new taxon in his honor. Additionally, we hope to do the same for Joe Rosewater. Personal reminiscences about either malacologist will be most welcome.

Although *The Nautilus* is independent of any university or museum, it has existed only because of the support from individual malacologists and private collectors. During my 27 years as an editor, I have been most appreciative of this support, and I hope that the next editor, who ever he or she may be, will carry on in the same cooperative spirit.

CHAETOPLEURA STAPHYLOPHERA (POLYPLACOPHORA: CHAETOPLEURIDAE), A NEW SPECIES FROM THE SOUTHEASTERN UNITED STATES AND BAHAMAS

William G. Lyons
Florida Department of Natural Resources
Bureau of Marine Research
St. Petersburg, FL 33701

ABSTRACT

Chaetopleura staphylophera *n. sp., from off North Carolina, the Bahamas, and both Florida coasts, differs from other western Atlantic* Chaetopleura *by possession of considerably larger, nonaligned pustules on end valves and lateral areas of intermediate valves, and from the west American* C. gemma *in that pustules of that species are aligned in radial rows. Relegation of* Calloplax *Thiele, 1909, to synonymy with* Chaetopleura *Shuttleworth, 1853, is recommended.*

Investigations of continental shelf fauna of relatively deep waters off Florida and adjacent areas have revealed a previously unknown species of the genus *Chaetopleura* Shuttleworth, 1853, which is here described. Questions regarding generic placement of this and another species prompted review of characters of *Chaetopleura* and of the genus *Calloplax* Thiele, 1909.

Most specimens examined during this study were collected during the Hourglass Cruises off central west Florida (Joyce and Williams, 1969), a survey of rock shrimp off northeast Florida (Kennedy *et al.*, 1977), and a study of the fauna of *Oculina* reefs off central east Florida (Avent *et al.*, 1977; Reed *et al.*, 1982). The first two programs were conducted by the Florida Department of Natural Resources Bureau of Marine Research utilizing the R/V *Hernan Cortez*, and the third was conducted by Harbor Branch Foundation utilizing the submersible *Johnson-Sea-Link* (JSL). Specimens are housed in the U.S. National Museum of Natural History, Smithsonian Institution (USNM), Washington, DC; the Academy of Natural Sciences of Philadelphia (ANSP), Pennsylvania; the American Museum of Natural History (AMNH), New York; the Brevard Museum, Inc. (BMI), Cocoa, Florida; the British Museum (Natural History) (BMNH), London; the California Academy of Sciences (CAS), San Francisco; the Harbor Branch Foundation (HBF; museum prefix IRCZM), Ft. Pierce, Florida; the University of North Carolina Marine Science Institute (UNC), Morehead City; and the Florida Department of Natural Resources Bureau of Marine Research (FDNR; museum prefix FSBC I), St. Petersburg. Because nearly all specimens were curled to some extent, measurements of total length are to the nearest 0.5 mm; individual valve-lengths are measured at the midline.

Chaetopleura staphylophera*, new species*

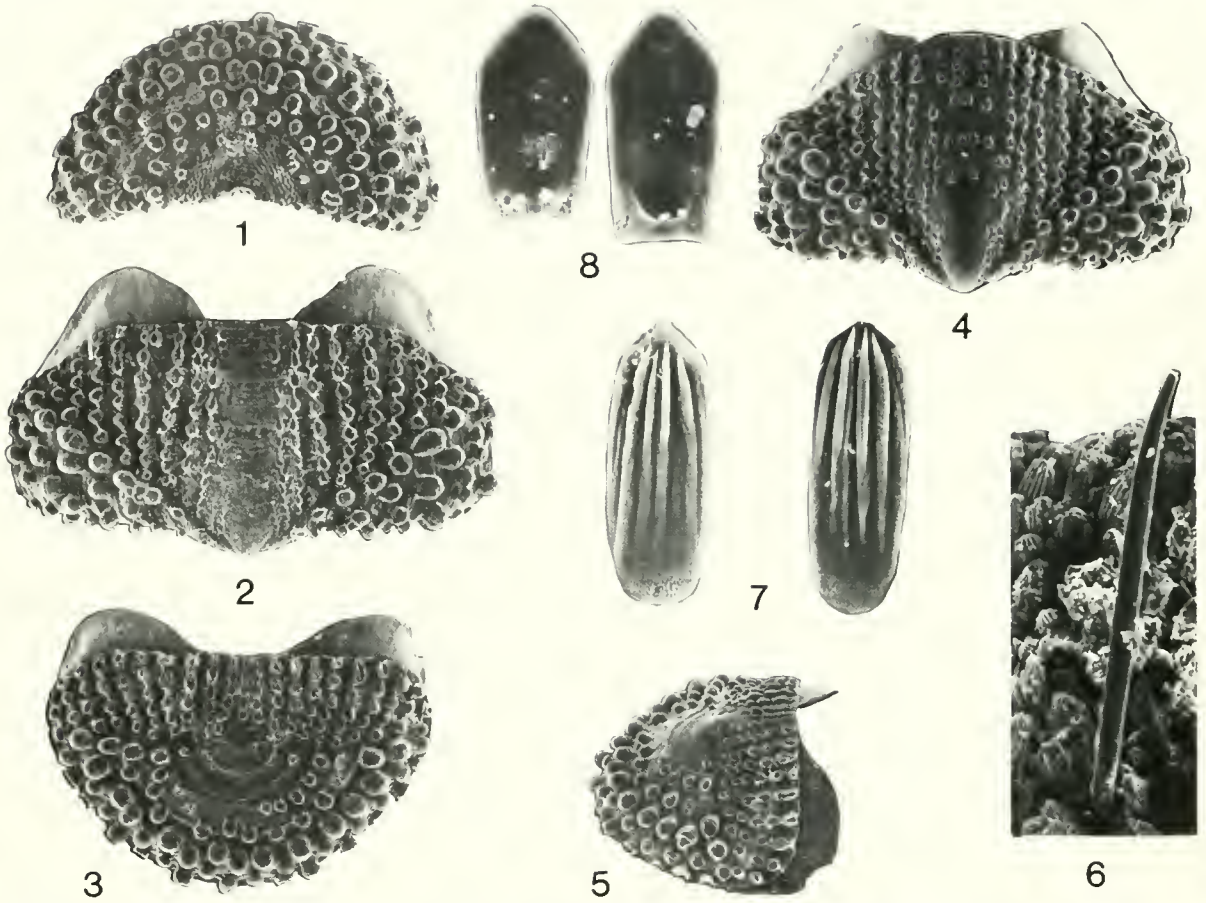
(Figs. 1-14, 28)

?Calloplax janeirensis: Porter, 1974, p. 302 [*non C. janeirensis* (Gray, 1828)].

Chaetopleura sp. Lyons, 1982, p. 39.

Holotype: Length 15.5 mm; Hourglass Station M; 26°24′N, 83°43′W, approximately 92 nmi west of Sanibel Island Light, Florida west coast; 73 m depth; 12 April 1966; USNM 842109.

Other material: FLORIDA: 1 paratype, 15.0 mm; Hourglass Station M; 12 April 1966; FSBC I 31757.– 1 paratype, 17.0 mm; same; 13 November 1966; FSBC I 31759.– 1 paratype, 11.5 mm; Hourglass Station D; 27°37′N, 83°58′W, approximately 65 nmi west of Egmont Key; 55 m; 4 April 1967; FSBC I 31758.– 1 paratype, dried, curled; *Eolis* Station 104; off Fowey Light; 91 m; J. B. Henderson, coll.; USNM 454682.– 1 paratype, 21.0 mm; 27°13.1′N, 79°58.7′W, 9 nmi ENE of St. Lucie Inlet; 64 m; 14 April 1973; FSBC I 31760.– 2 paratypes, 11.0, 15.0 mm; JSL Station 2122A; 27°32.8′N, 79°58.8′W, east of Ft. Pierce; 77.4 m; 20 September 1976; IRCZM 61:060.– 2 paratypes, 6.0, 8.5 mm; JSL Station 2125A; same



FIGS. 1-8. **1-6,** *Chaetopleura staphylophera* n. sp., paratype, 15.0 mm; west of Sanibel Island, Florida, 73 m; FSBC I 31757: 1, valve I; 2, valve IV; 3, valve VIII; 4, valve II; 5, valve VIII, lateral view (all × 15); 6, girdle spicule (× 220); **7,** *C. staphylophera*, paratype, 16.0 mm; 23.5 nmi east of Port Canaveral, Florida, 73 m; FSBC I 31761; dorsal girdle scales (× 515); **8,** same; ventral girdle scales (× 550).

coordinates; 77.7 m; 21 September 1976; IRCZM 61:061.– 4 paratypes, 1.5-8.5 mm; JSL Station 2160A; same coordinates; 73.8 m; 2 February 1977; IRCZM 61:062.– 1 paratype, 7.0 mm; JSL Station 2163A; same coordinates; 80 m; 7 February 1977; IRCZM 61:063.– 1 paratype, 1.8 mm; JSL Station 2163B; same coordinates, depth, and date; IRCZM 61:064.– 1 paratype, 16.0 mm; [?] 28°02′N, 80°26′W, 8 nmi east of Grant; 18 m; 6 June 1978; BMI 1143.– 2 paratypes, 9.0, 10.0 mm; 28°02.8′N, 79°58.0′W, 31.5 nmi SE of Port Canaveral; 73 m; 22 May 1973; ANSP A-10629.– 1 paratype, 12.0 mm; 28°10′N, 80°03′W, 30 nmi ENE of Melbourne; 53 m; September 1981; AMNH 213570.– 2 paratypes, 6.5, 16.0 mm; 28°18.9′N, 79°59.1′W, 23.5 nmi east of Port Canaveral; 73 m; 19 June 1973; FSBC I 31761.– 1 paratype, 13.5 mm; 28°35′N, 80°07′W, 24 nmi ENE of Cape Canaveral; 61 m; July 1982; BM(NH) 1985007.– 1 paratype, 9.5 mm; 28°37.1′N, 80°04.8′W, 25 nmi ENE of Cape Canaveral; 61 m; 14 August 1973; CAS 056545.– 1 paratype, 18.0 mm; 28°41′-40′N, 80°03′W, 28 mi ENE of Cape Canaveral; 86-91 m; 23 April 1983; FSBC I 30775.– 1 paratype, 13.0 mm; 30°00′N, 80°15′W, 54 nmi ENE of St. Augustine; 73.1-82.2 m; 24 June 1982; FSBC I 30771. NORTH CAROLINA: 1 paratype, 14.5 mm; *Eastward* Station 480; 34°12′N, 76°05.9′W, SE of Cape Lookout; 73-107 m; 18 March 1969; UNC 4302.1– GRAND BAHAMA ISLAND: 1 tail valve (viii), 7.3 mm wide, 4.2 mm long; Gold Rock; 24.4 m; J. N. Worsfold, coll.; July 1981;

FSBC I 31762.– 1 tail valve (viii), 7.0 mm wide, 3.8 mm long; Tamarind Beach Reef; 46.8 m; Worsfold collection.– 1 intermediate valve, 7.2 mm wide, 3.1 mm long at jugum; Gold Rock; 26.2 m; Worsfold collection.– 1 intermediate valve, 9.9 mm wide, 4.5 mm long at jugum; Indian Cay; 23.0 m; Worsfold collection.

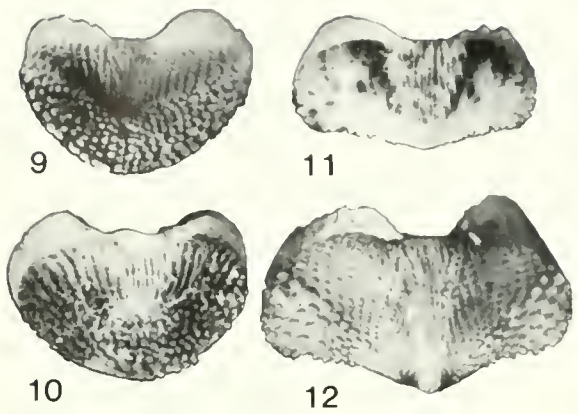
Description: Largest entire specimen 21.0 mm long, 9.5 mm wide, including girdle. Some paratypes bright orange; holotype and other paratypes yellow or beige with white stripe on jugum; stripe sometimes overlain with orange, anteriorly directed, slender triangle; or, in addition, with dark brown in central areas of valves ii, iv, v, vii, and viii. Tegmentum ornamented with rounded, large pustules (to 300 μm diameter) and linearly aligned, usually small (to 150 μm diameter) pustules. Width of tegmentum of valves of undissected holotype: i=3.6; ii=4.1; iii=4.5; iv=4.6; v=4.8; vi=4.9; vii=4.5; viii=3.6 mm. Head valve (i) ornamentation beginning as radial rows of 3 or 4 small pustules at apex, thereafter losing alignment but closely situated, increasing in size toward margin, resulting in vaguely concentric arcs of pustules of similar size. Lateral areas of intermediate valves (ii-vii) with about 30-50 large pustules, seldom if ever connected, those at anterior margins aligned in transverse rows, others scattered, all closely packed, increasing in size toward anterolateral corners; central areas with as many as 19 or 20 subparallel, occasionally converging, longitudinal rows of small pustules (8-9 rows on holotype); pustules of rows increasing in size and decreasing in numbers toward lateral margins; as many as 20 small pustules in rows near jugum; rows usually continuing over jugum of valves ii and vii, sometimes absent or interrupted at jugum of valves iii-vi; posterior edges of intermediate valves straight in larger specimens, slightly beaked in smaller specimens, all slightly peaked (subcarinate) at center. Tail valve (viii) with mucro slightly elevated, a little anterior of center, thereafter dropping away concavely for a short distance and then sloping gently to posterior margin; jugum and central areas with parallel rows of small pustules; remainder of valve with large, densely packed pustules arranged in concentric rows of pustules of similar size, largest at margin.

Articulamentum white, with light brown or orange hues evident through strongly excavate surfaces beneath lateral areas, somewhat less evident beneath central areas, occasionally with an orange, longitudinal stripe beneath jugum. Insertion teeth well defined, relatively sharp, thickened near slit; slit formula 11-1-8. Sutural laminae relatively short, broadly rounded anteriorly; sinus well defined; on valve viii of 16.0 mm specimen, width of sinus 0.9 mm, width of sutural laminae 2.4 mm; ratio (relative width of sinus) 0.375. Eaves solid.

Girdle upper surface paved with small (about 70-75×20-35 μm), ovoid, elongate scales, coarsely striated toward sometimes pointed distal tips, interspersed with a few glassy spicules up to 350 μm long; girdle outer margin fringed with glassy spicules of two types, the first slender, blade-like (30×210 μm), the other very slender and small (8-10×55-80 μm); undersurface paved with rectangular, transparent scales about 25×50-100 μm, each bearing an outer edge protuberance that articulates with inner edge concavity of adjacent scale; girdle bridges packed with slender, blade-like spicules (10×115 μm).

Radula of 16.0 mm specimen 5.0 mm long (31% of total specimen length), with 48 rows of mature teeth; median tooth broadly rectangular, about 90 μm wide at anterior blade; major lateral teeth with tricuspid head 120 μm long, 80 μm wide.

Variation: The 27 intact specimens range in length between 1.5 and approximately 21.0 mm. No pustules are present on two specimens 1.5 and 1.8 mm in length, but a 2.2 mm specimen (IRCZM 61:062) has single large pustules at anterolateral corners of each intermediate valve, indicating that tegmental ornamentation may begin at about that size. Thereafter, large pustules of all valves apparently increase in size and number with increasing size of the animal. The largest specimen (21.0 mm; FSBC I 31760; Fig. 14) is severely eroded on all valves, particularly at the junctions of lateral and central areas of the intermediate valves. The rows of small pustules of central areas extend over the jugum of all valves except iv, which remains smooth on the posterior half; indications of 19-20 pustule rows are present on some valves. In lateral areas of the 21.0 mm specimen, largest pustules tend to occur near the middle, and pustules nearest the girdle are somewhat



FIGS. 9-12. Single valves of *Chaetopleura staphylophera* n. sp. from sediments, Grand Bahama Island (all × 3.5): **9**, valve VIII; Gold Rock, 24.4 m; FSBC I 31762; **10**, valve VIII, Tamarind Beach reef, 46.8 m; **11**, intermediate valve; Gold Rock, 26.2 m; **12**, intermediate valve; Indian Cay, 23.0 m. [Figured specimens 10-12 in Worsfold collection].

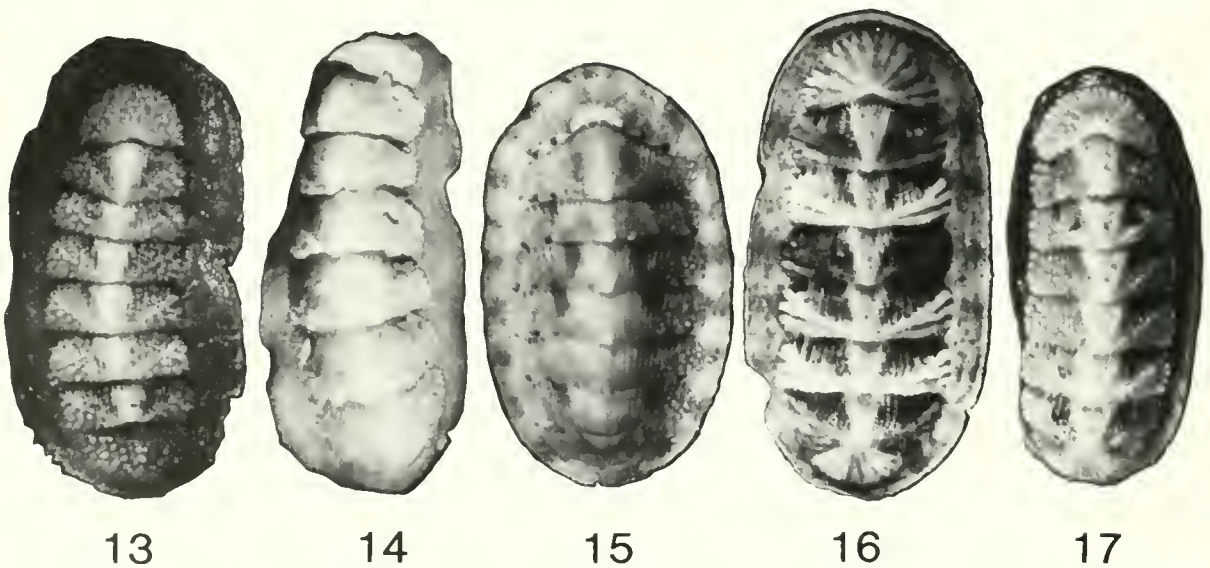
smaller and arranged in rough, concentric arcs, giving the impression of less energetic growth with advanced age.

The Bahamian specimens consist only of single valves (Figs. 9-12), but their tegmental pustular arrangements are similar to those of specimens from North Carolina and Florida. If, as seems likely, the Bahamian specimens represent the new species, this may indicate that the species attains greater size than exhibited by the largest (21.0 mm) entire specimen; width of the tegmentum of valve viii of that specimen is only 5.2 mm, whereas that of the largest Bahamian specimen is 7.3 mm.

Distribution: Intact specimens of *Chaetopleura staphylophera* were examined from off Tampa Bay and Sanibel Island, Florida west coast; off Fowey Light near Miami; offshore of St. Lucie Inlet northward to St. Augustine along the Florida east coast; and southeast of Cape Lookout, North Carolina. Because all other Florida specimens were taken from depths of 53-91 m, the single record from 18 m (BMI 1143) is questioned. The North Carolina collection is from "240-350 ft" (=73-107 m), so that specimen may have occurred within the depth range of the Florida material or in slightly greater depths. All Bahamian specimens are from off the southwest coast of Grand Bahama Island and consist only of single valves collected by divers from sediments near reefs in 23-47 m depths, somewhat shallower than the continental collections.

Etymology: The specific name *staphylophera*, from the Greek *staphyle* (a bunch or cluster of grapes) and *phero* (to bear or carry), refers to the distinctive clusters of large, grape-like pustules on lateral areas of intermediate valves.

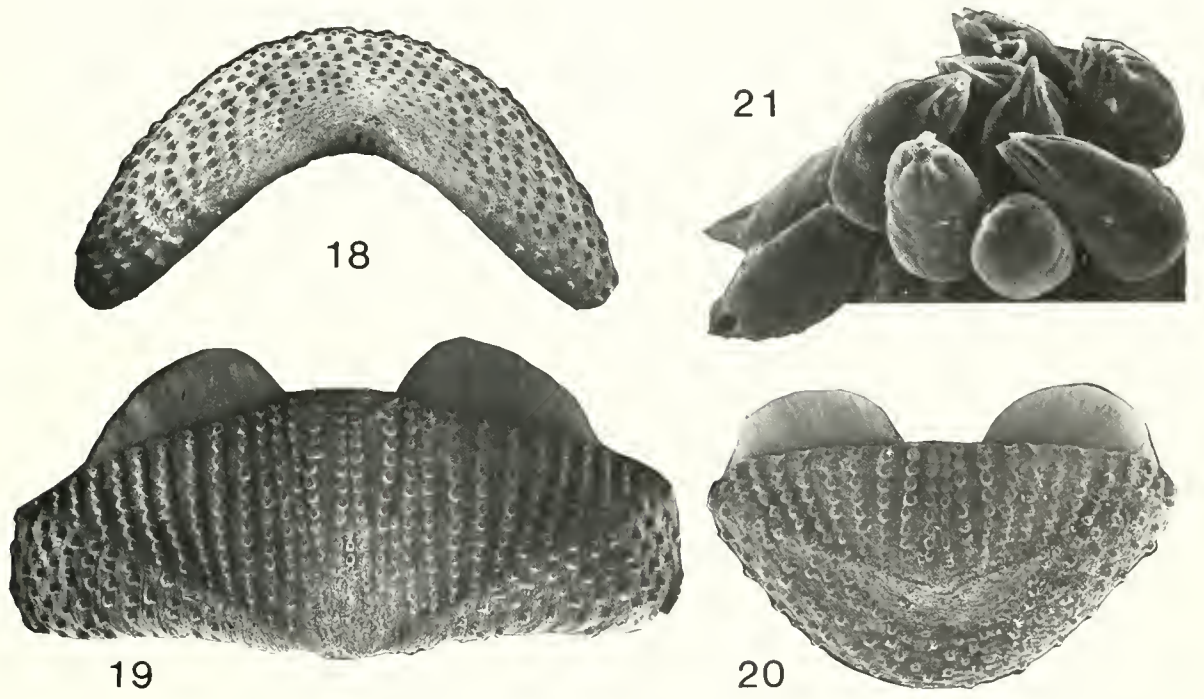
Remarks: Porter (1974: p. 302) listed the



FIGS. 13-17. **13**, *Chaetopleura staphylophera* n. sp., holotype, 15.5 mm; west of Sanibel Island, Florida, 73m; USNM 842109. **14**, *C. staphylophera*, paratype, 21.0 mm; 9 nmi ENE of St. Lucie Inlet, Florida, 64 m; FSBC I 31760; **15**, *Chaetopleura apiculata* (Say), 12.4 mm; east of Hutchinson Island, Florida, 91.5 m; FSBC I 30767; **16**, *"Callochiton" janeirensis* (Gray), 18.0 mm; Sand Key reef, Florida, 1 m; FSBC I 31765; **17**, *"C." janeirensis*, 16.0 mm; Rio de Janeiro, Brazil, shallow; FSBC I 31768.

North Carolina specimen as *?Calloplax janeirensis*, and Lyons (1982: p. 39) mentioned an undescribed species of *Chaetopleura* from the Bahamas. Both reports were based upon specimens used in this study and which are herein described.

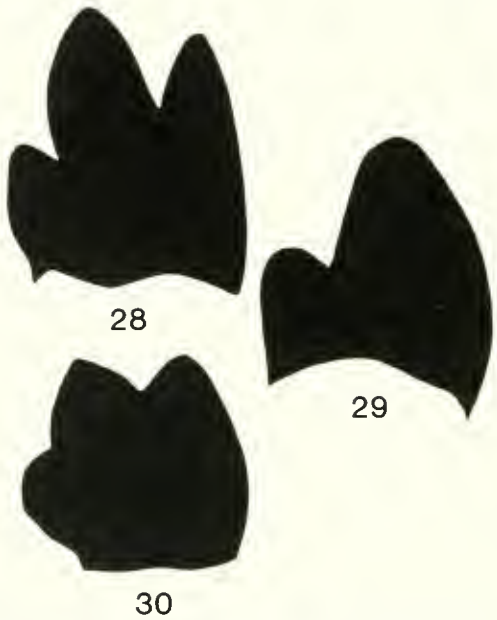
The new species differs from *Chaetopleura apiculata* (Say, 1834), the only previously known *Chaetopleura* species from the eastern and southern United States, by possession of much larger, more densely arrayed pustules on the end valves and on lateral areas of intermediate valves (Figs. 18-20). Additionally, the major lateral tooth of the radula of *C. apiculata* is bicuspid (Fig. 29), whereas that of the new species is tricuspid (Fig. 28). In areas where the ranges of the two species overlap latitudinally, *C. apiculata* usually (but not always) occupies shallower depths than does *C. staphylophera*. Other western Atlantic species of *Chaetopleura* are known only from the southern Caribbean or further south. These include *C. candisata* Shuttleworth, 1856 (=*C. apiculata, fide* Kaas, 1972; Kaas and Van Belle, 1980; Ferreira, 1983a), from Guadeloupe, and *C. angulata* (Spengler, 1797), *C. isabellei* (d'Orbigny, 1841), and *C. spinulosa* (Gray, 1828), all from Brazil or southward to Patagonia. Published descriptions of the last three species indicate that all possess tegmental pustules considerably smaller and more widely spaced than those of the new species. *Chaetopleura carrua* Righi, 1970, entirely lacks pustules on end valves and lateral areas of intermediate valves. Instead, *Chaetopleura staphylophera* demonstrates a close relationship to *Chaetopleura gemma* Dall, 1879, a west American species which occurs from Vancouver Island, Canada, to Magdalena Bay, Baja, California (Burghardt and Burghardt, 1969; Putnam, 1980). That species lives in depths of 10-40 fms (18-73 m) or more according to Clark (1982), but Ferreira (1983a) reports the bathymetric range as 0-22 m; the reason for this discrepancy is unknown. Like the new species, the major lateral tooth of the radula of *C. gemma* is tricuspid (Dall, 1879: 296, pl. 1, fig. 9). Tegmentum color, size and shape of pustules, and slit formula (9-12/1/7-8) of *C. gemma* are also similar to those of *C. staphylophera*, but pustules of the lateral areas of *C. gemma* are arranged in 4-7 radiating rows (Pilsbry, 1892; Ferreira, 1983a), whereas those of *C. staphylophera* are not



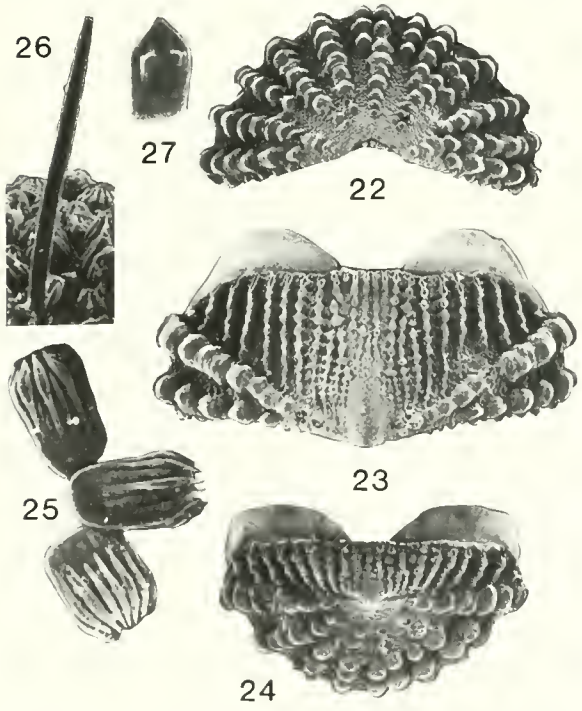
FIGS. 18-21. *Chaetopleura apiculata* (Say), 11.0 mm; Anclote Key, Florida, 3 m; FSBC I 31764: **18**, valve I; **19**, valve IV; **20**, valve VIII (all × 16); **21**, dorsal girdle scales (× 600).

aligned except at anterior margins. Likewise, there are 10-15 longitudinal rows of pustules on central areas of *C. gemma* (*fide* Ferreira, 1983a), whereas *C. staphylophera* has as many as 20 such rows. The tail valve of *C. gemma* illustrated by Pilsbry (1892: pl. 13, fig. 74) also differs from that of *C. staphylophera*, being ornamented with many radial rows of numerous beads rather than the essentially nonaligned pustules of the new species.

Chaetopleura staphylophera is distinguished from *Calloplax janeirensis* [also = *Chiton souverbiana* Reeve, 1847, formerly considered a species of *Chaetopleura*, *fide* Ferreira (1979)], the only other species of Chaetopleuridae in Florida and the northern Caribbean, by possession in the latter of strong radial ribs (Fig. 16) or rows of loosely coalesced pustules (Figs. 17, 22-24) instead of unaligned pustules on end valves and lateral areas of intermediate valves. However, the new species resembles *C. janeirensis* in the size and shape of pustules, in the pebbly surface of the interpustular tegmentum of head and tail valves (Figs. 1, 3, 22, 24), and in morphology of scales (Figs. 7, 8, 25, 26) and scattered glassy spicules (Figs. 6, 27) of the dorsal surface of the girdle. Both species also possess radulae with tricuspid major lateral teeth, but cusps are much longer and more acute on teeth of *C. staphylophera* than are those of *C. janeirensis* (Fig. 30).



FIGS. 28-30. Major lateral radular teeth: **28**, *Chaetopleura staphylophera* n. sp. (× 450); **29**, *Chaetopleura apiculata* (× 400); **30**, *"Calloplax" janeirensis* (× 500).



FIGS. 22-27. **22-25**, *"Calloplax" janeirensis* (Gray), 10.5 mm; Dry Tortugas, Florida, 1 m; FSBC I 31767: **22**, valve I; **23**, valve IV; **24**, valve VIII (all × 12); **25**, dorsal girdle scales (× 300); **26**, *"C." janeirensis*, 15.5 mm; Key Vaca, 1 m; FSBC I 31766; girdle spicule (× 200); **27**, *"C." janeirensis*, 14.5 mm; Key Vaca, Florida, 1 m; FSBC I 31766; ventral girdle scale (× 300).

Ferreira's statement (1983a: p. 220) that *Chaetopleura gemma* "poses no diagnostic problems [as a species of *Chaetopleura*] given its very different characteristics in shape, size and sculpture [including "tubercular ridges" on lateral areas]" is perplexing because that species, like *C. staphylophera*, also strongly resembles *Calloplax janeirensis*. Efforts to clarify the generic affinities of these species prompted a review of recent treatments of both genera.

Thiele (1909) erected *Calloplax* to contain *Chiton janeirensis* Gray, 1828, which occurs from Brazil to south Florida. Assigned to *Chaetopleura* Shuttleworth, 1853, by several authors during the latter half of the nineteenth century, *C. janeirensis* was separated from that genus by Thiele because the pustules of the head, tail, and lateral areas of intermediate valves are much

larger than those of species of *Chaetopleura* and are usually coalesced to form prominent ribs. *Calloplax* was placed in Chaetopleuridae by Thiele (1929) where it remained until recently. No additional species were described until A. G. Smith and Ferreira (1977) reassigned the endemic Galapagos species *Callistochiton duncanus* Dall, 1919, to *Calloplax*, thereby establishing the presence of the genus in the eastern Pacific; Smith and Ferreira concurrently reassigned *Calloplax* to Callistoplacidae. Soon thereafter, Ferriera (1978) transferred a Chilean species, *Callistochiton viviparus* Plate, 1899, to *Calloplax*, redescribed *C. janeirensis* and *C. duncanus*, reviewed synonymies of all three and retained *Calloplax* in Callistoplacidae. More recently, Ferreira (1982) described a third eastern Pacific species, *Calloplax hanselmani*, from Peru and the Galapagos Islands northward to Mexico. In that paper, Ferreira expressed uncertainty regarding the taxonomic position of *Calloplax* and, after assessing similarities between *Calloplax*, *Chaetopleura* and *Callistochiton*, concluded that *Calloplax* should be returned to Chaetopleuridae.

Although Ferreira (1978, 1982) twice provided diagnostic comments for *Calloplax* and most recently (1983a) provided similar comments for *Chaetopleura*, he did not define characters separating species of the two genera. Difficulty in identifying differences between the genera has been complicated by unequal application of diagnostic characters. Thus, Ferreira's (1982) diagnosis of *Calloplax* mentions overall shape, tegmental ornamentation, location and configuration of the mucro, and girdle ornamentation, whereas his (1983a) diagnosis of *Chaetopleura* includes comments on size, tegmental ornamentation, insertion plates, slits of intermediate valves, eaves, girdle ornamentation, gills, and radular morphology. To allow more equitable comparison of the two genera, information on the above characters and on girdle bridges (see Ferreira, 1983a) was compiled from species descriptions as well as diagnoses in each of Ferreira's three papers (Table 1).

Information in Table 1 reveals that although some species of *Chaetopleura* have features (e.g., small pustules on head and tail valves and lateral areas of intermediate valves; girdle hairs; bicuspid major lateral tooth) not found on any species of *Calloplax*, all features except the radial ribs of some species of *Calloplax* are fully contained within the range of characters of *Chaetopleura*. In fact, *Calloplax hanselmani* has radial rows of unconnected pustules, not ribs, in areas where ribs customarily occur on species assigned to *Calloplax*, and even ribs of *C. janei-*

TABLE 1. Diagnostic Characters in Recent Reviews[1] of *Chaetopleura* and *Calloplax*.

Character	*Chaetopleura*	*Calloplax*
Size[2]	Small to large (8-60 mm length).	Small to medium (13-21 mm length).
Shape	Ovate (length/width ratio 1.4-1.8:1).	Elongate (length/width ratio ca. 2:1).
Tegmentum	Larger pustules in quincunx or radial rows in end valves and lateral areas of intermediate valves; smaller pustules in longitudinal rows or coalesced in riblets in central areas.	Strong radial ribs or rows of pustules in end valves and lateral areas of intermediate valves; longitudinal, often granulose riblets in central areas.
Insertion plates	With "rather sharp" teeth.	With "*Callistochiton*-like" to "relatively sharp" teeth.
Intermediate valves	Uni-slit.	Uni-slit.
Eaves	Solid.	Solid.
Mucro	Posterior, central or slightly anterior, with concave or convex postmucro, with or without additional false mucro.	Central or slightly anterior, with convex postmucro.
Girdle	With minute, simple, oval to spiculoid scales, interspersed with glassy, hyaline spicules; some species with horny hairs.	With spicules (not hairs) interspersed amidst small, ovoid, closely packed, coarsely striated scales.
Girdle bridges	With or without spicular elements.	With or without spicular elements.
Gills	Holobranchial, abanal.	[Not defined].
Radula	Median tooth wide, subquadrangular; major lateral teeth tricuspid or bicuspid.	Median tooth wide, subquadrangular; major lateral teeth tricuspid.

[1]From Ferreira (1978, 1982, 1983a)
[2]Ranges based on largest reported sizes of various species.

rensis occur as rows of loosely connected pustules in some specimens from Florida (Figs. 22-24) and Rio de Janeiro (Fig. 17), the type-locality of the type-species of *Calloplax*. This seems to eliminate the value of radial ribs as a generic character and requires the conclusion that *Calloplax* is a junior synonym of *Chaetopleura*.

A brief review based upon morphological information available in published literature (Pilsbry, 1892; Thiele, 1893; Plate, 1899; Righi, 1967, 1970; Bullock, 1972; Ferreira, 1978, 1982, 1983a) suggests that most of the 22 New World species of Chaetopleuridae are separable into two groups as defined by Pilsbry (1892: p. 28): "(1) typical forms, rather large, and having very delicate sculpture; and (2) group of *C. gemma*, having the lateral areas strongly raised and coarsely sculptured." These groups approximate those previously allotted to *Chaetopleura* and *Calloplax*, but some "intermediate" species do not conform fully to either group (Table 2).

The first group is comprised of species with bicuspid lateral radular teeth, corneous girdle hairs in addition to scales and glassy spicules, and small tegmental pustules widely scattered or separated in rows. This group includes *Chaetopleura angulata* (Spengler, 1797), *C. apiculata* (Say, 1834), *C. asperrima* (Gould, 1852), *C. hennahi* (Gray, 1828), *C. iquiquensis* (Plate, 1899) and *C. peruviana* (Lamarck, 1819). Radulae of *C. benaventei* Plate, 1899, and *C. fernandensis* Plate, 1899, have not been described, but these species closely resemble *C. peruviana* and *C. iquiquensis*, respectively, in other characters (see Ferreira, 1983a: p. 221), so they also may belong to this group. Ferreira (1983a) implied that *C. unilineata* Leloup, 1954, lacks girdle hairs, but a photograph (his fig. 28) seems to show scattered hairs on the girdle of that species; if present, they would place *C. unilineata* in this group as well. I am unable to ascertain whether *C. isabellei* (d'Orbigny, 1841) or *C.*

TABLE 2. Groupings of New World *Chaetopleura* species, based upon features of the girdle, radula and tegmentum.

Species	Tegmental pustules absent	Lateral radular bicuspid tooth	Girdle hairs present	Tegmental pustules small	Lateral radular tricuspid tooth	Girdle hairs absent	Tegmental pustules "intermediate"	Tegmental pustules large	Tegmental pustules fused, 2 solid ribs
C. carrua	x	x	?						
C. angulata		x	x	x					
C. apiculata		x	x	x					
C. asperrima		x	x	x					
C. hennahi		x	x	x					
C. iquiquensis		x	x	x					
C. peruviana		x	x	x					
C. benaventei		?	x	x					
C. fernandensis		?	x	x					
C. isabellei		x	?	x					
C. spinulosa		x	?	x					
C. unilineata		x	?	x					
C. scabricula			x	x	x				
C. lanuginosa				x	x	x			
C. roddae					x	x	x		
C. shyana					x	x	x		
C. gemma					x	x		x	
C. hanselmani					x	x		x	
C. janeirensis					x	x		x	
C. staphylophora					x	x		x	
C. duncana					x	x			x
C. cucullata					x	x			x

spinulosa (Gray, 1828) have girdle hairs; if so, those species also belong here. The type-species of *Chaetopleura* is *Chiton peruvianus* Lamarck [subsequent designation, Dall (1879)], so species in this group would best typify *Chaetopleura s.s.*

Although central areas of its intermediate valves bear rows of tiny, coalesced pustules, *Chaetopleura carrua* Righi, 1970, entirely lacks tegmental pustules on head and tail valves and on lateral areas of intermediate valves. In this regard, *C. carrua* resembles *C. angulata*, a species in which tegmental pustules may be nearly obsolete. Its bicuspid radula appears to ally *C. carrua* with the above group.

Chaetopleura scabricula (Sowerby, 1832) also resembles species in the above group by having small tegmental pustules and distinct girdle hairs but differs by having tricuspid lateral teeth. *Chaetopleura lanuginosa* (Dall, 1879) likewise resembles species in the first group by having small, scattered tubercles but lacks girdle hairs and has tricuspid lateral teeth.

Chaetopleura roddae Ferreira, 1983, and *C. shyana* Ferreira, 1983, each lack girdle hairs, have tricuspid lateral teeth, and have densely packed unaligned tegmental pustules on head and tail valves and lateral areas of intermediate valves. Although relatively smaller than pustules on species in the following group, densities and arrangements of these pustules are suggestive of some species in that group.

The next group includes *C. janeirensis*, the type-species of *Calloplax*. In addition, *Chaetopleura gemma* Dall, 1879, *C. staphylophera*, n. sp., and *C. hanselmani* (Ferreira, 1982) all lack girdle hairs, have tricuspid lateral teeth, and have large tegmental pustules on the head and tail valves and lateral areas of intermediate valves. Pustules may be unaligned (*C. staphylophera*) or arranged in rows (*C. gemma, C. hanselmani, C. janeirensis*) which sometimes in *C. janeirensis* coalesce into radial ribs; two or more such ribs may occur on lateral areas of intermediate valves. Girdle scales and spicules of species in this group resemble those of other species in the group moreso than they resemble those of any other *Chaetopleura* species (for example, see *C. apiculata*, Fig. 21).

Chaetopleura duncana (Dall, 1919) and *C. vivipara* (Plate, 1899) pose additional problems in placement. Each lacks girdle hairs, has tricuspid lateral teeth, has strong radial ribs on head and tail valves, and has only two such ribs on lateral areas of intermediate valves. The low, conical or dome-like girdle scales of these species as illustrated by Ferreira (1978) are dissimilar from any other species of Chaetopleuridae.

Additionally, there are at least three species of *Chaetopleura* in South Africa, possibly two in west Africa, one in east Africa, and one in east Asia (Ferreira, 1983a, b). Insufficient information is available to determine where most of these fit in the above arrangement.

Acknowledgments

Hugh J. Porter, University of North Carolina Marine Science Institute, Morehead City, provided his previously reported specimen for study. John Reed and Dr. Robert Avent allowed study of material collected during their study of the deep-water *Oculina* reef community, sponsored by the Harbor Branch Foundation, off central eastern Florida. Johnnie Johnson, Brevard Museum, Inc., provided specimens from the calico scallop grounds near Cape Canaveral. Jack N. Worsfold, Freeport, Grand Bahama, provided the single valves from that area. Lana Tester, formerly FDNR Bureau of Marine Research, produced the SEM photomicrographs, and Sally D. Kaicher provided additional darkroom assistance. Dr. James F. Quinn, Jr., FDNR, provided guidance in Greek grammar. All are gratefully thanked.

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Conchologists of America

The annual meeting of the Conchologists of America will be held in Philadelphia June 22-26, 1985, where it will be hosted by the Philadelphia Shell Club at the Academy of Natural Sciences of Philadelphia and a nearby hotel. For reservation forms write: Frank Roach, 1028 Belvoir Rd., Norristown, PA 19401.

1985 AMU Meeting

The American Malacological Union will hold its annual meeting on the campus of the University of Rhode Island on July 29-August 3, 1985. For further information please contact Dr. M. R. Carriker, College of Marine Studies, University of Delaware, Lewes, DE 19958.

ARENE FLEXISPINA, A NEW SPECIES (GASTROPODA: LIOTIIDAE) FROM OFF EASTERN BRAZIL

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Seven species of the genus *Arene* H. & A. Adams, 1854 are already known from the Brazilian coast: *Arene tricarinata* (Stearns, 1872), *A. briareus* (Dall, 1881), *A. variabilis* (Dall, 1889), *A. bairdii* (Dall, 1889), *A. brasiliana* (Dall, 1927), *A. riisei* Rehder, 1943 (Abbott, 1974; Rios, 1975) and *A. notialis* Marini, 1975 (Marini, 1975). The present description is based on specimens obtained through bottom sampling (van Veen and Petersen grabs) between 54 and 82 meter depth during the GEOMAR X cruise undertaken by the Brazilian Navy research vessel "N.Oc. Almirante Câmara" along the eastern coast of Brazil, in the period of 01-11 June 1978. Sampled substrate in the three stations where the species was found consisted of fragments of calcareous algae and calcareous gravel. Although soft parts are not preserved, thus making difficult a more accurate taxonomic characterization, shell features are markedly distinct.

Arene flexispina *new species*

(Figs. 1-3)

Description: Shell small, solid, trochoid in shape, reddish brown, with spiral rows and spines of lighter color. Ratio height/width of the shell higher in adults than in younger specimens. Whorls 5½, the first 1½ comprising the protoconch, white and smooth, lower than the subsequent whorl. Teleoconch whorls with 2 larger peripheral spiral rows of 10 or 11 large, fluted spines spirally raised and imbricated. Narrower row 1-2 subsutural, one intermediate (between the 2 larger) and one immediately above the subsequent whorl, with numerous imbricated scale-like spines, smaller than those in the 2 larger rows. Finely incised axial lines on entire shell microscopic and crowded. Suture channeled, clearly defined. Body whorl rounded, with wider spiral cords; spines in the 2 larger cords triangular, bent outwards and sharply pointed in apical view; spines number the same as in the spire. Base with 4 or 5 well-separated beaded spiral cords; beads almost imperceptible in worn specimens. Cord bordering the umbilicus the same size or only slightly larger than the other basal cords (younger specimens). Umbilicus wide, deep and twisted, with fine axial lines internally. One or two cords entering the umbilicus in younger shells, absent in mature specimens. Aperture whitish, oblique. Outer lip thin, with crenulations corresponding to the external spiral ornamentation. Operculum round, multispiral, with small radial lines giving beaded aspect to its calcareous external surface. Attachment side horny and convex.

Material examined: GEOMAR X station 048, 40 km off Ponta de Corumbaú, Bahia, Brazil (16°56′30″S, 38°39′30″W), 80 m depth, "N.Oc. Almirante Câmara" col. 09 June 1978, Holotype, Museu Nacional, Rio de Janeiro, Brazil (Col.Mol. MN 5352), height 6.4 mm, width 6.7 mm; Paratype 1, United States National Museum, Washington, D.C. (USNM 820786), height 5.4 mm, width 6.2 mm; Paratype 2 (Col.Mol.MN 5353), height 4.7 mm, width 5.4 mm; Paratype 3, Museu Oceanográfico, Fundação Universidade do Rio Grande, Rio Grande, Brazil (MORG 22807), height 3.5 mm, width 4.5 mm; Paratype 4 (USNM 820786A), height 3.4 mm, width 4.3 mm; Paratype 5 (MORG 22808), height 3.2 mm, width 4.3 mm; GEOMAR X station 038, 170 km off Conceição da Barra, Espírito Santo, Brazil (18°49′00″S, 37°52′00″W), 54 m depth, "N.Oc. Almirante Câmara" col. 07 June 1978, Paratype 6 (MORG 22619), height 2.0 mm, width 3.0 mm; GEOMAR X station 047, 120 km off Abrolhos Reef, Bahia, Brazil (17°44′00″S, 37°21′00″W), 54 m depth, "N.Oc. Almirante Câmara" col. 08 June 1978, Paratype 7 (Col.Mol.MN 5354), height 1.4 mm, width 2.4 mm.

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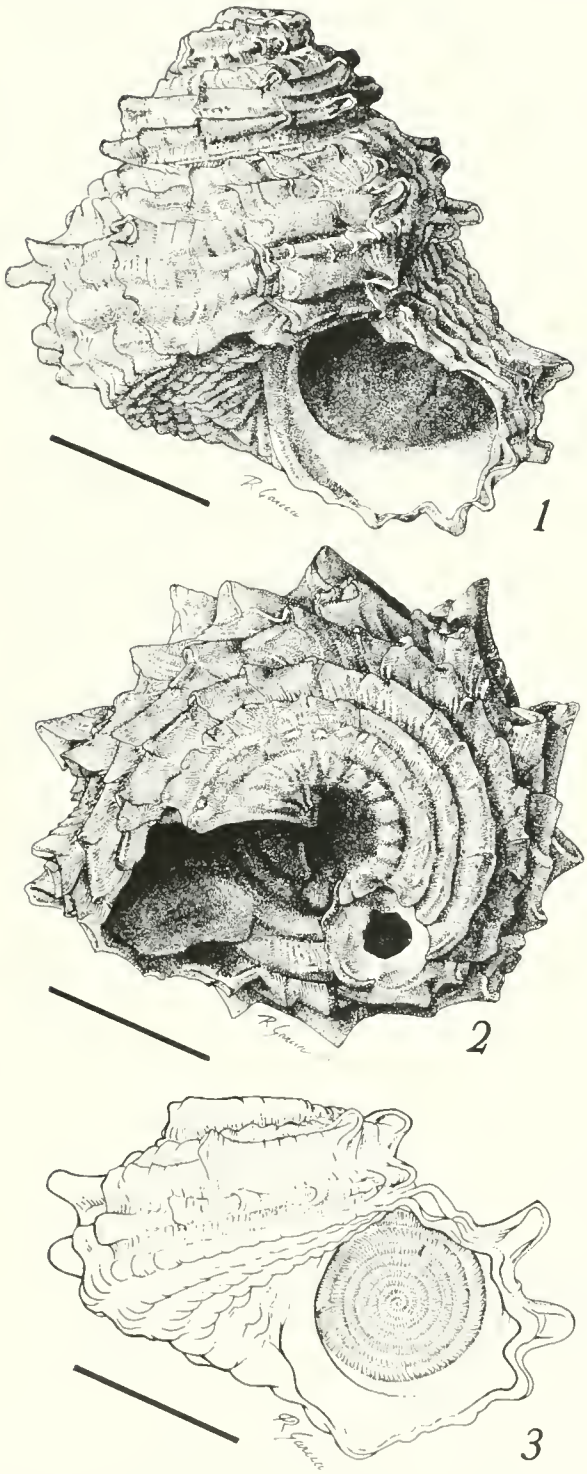
[2]Contribution no. 46



FIGS. 1-3. *Arene flexispina* n. sp. 1 and 2, Apertural and ventral views of the holotype, Col.Mol.MN 5352, 40 km off Ponta de Corumbaú, Bahia State, Brazil. Scale bar = 2 mm. 3, Apertural view with operculum of the paratype 6, MORG 22619, 170 km off Conceição da Barra, Espírito Santo State, Brazil. Scale bar = 1 mm.

Type locality: Brazil, Bahia State, 40 km off Ponta do Corumbaú, (16°56′30″S, 38°39′30″W), 80 m depth, calcareous algae bottom (Fig. 4).

Etymology: The specific name stands for the large outwardly bent spines in the spiral cords of the spire and body whorl.

Remarks: The species seems to belong in the subgenus *Arene s.s.* which is, as stated by Keen (1971:345), characterized by a sculpture of coarsely beaded spiral cording on the body whorl and base, the periphery rounded or stellate. Although *A. flexispina* n. sp. possesses some of the characters of the subgenus *Marevalvata* Olsson & Harbison, 1953, such as general outline, spiral cords in the umbilicus wanting in mature specimens and outer lip not thickened, it doesn't exhibit the diagnostic flattened base with radial lines extended from the umbilicus and a nacreous inner layer (Olsson & Harbison, 1953:348; Keen, 1971:346). Further investigations or a revision work on the western Atlantic species of *Arene* seems to be necessary to confirm the positioning of *A. flexispina* at subgeneric level.

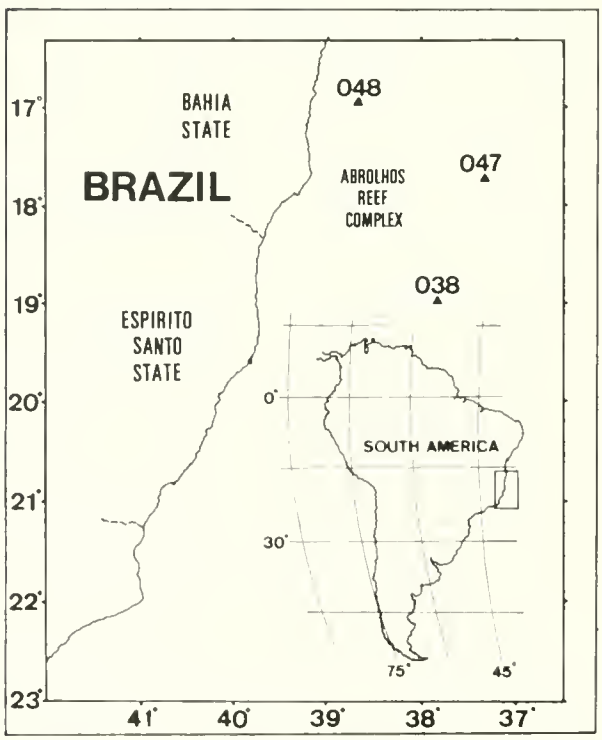


FIG. 4. Location of the three GEOMAR X stations in which *Arene flexispina* n. sp. was found (solid triangles). The type locality is represented by station 048. Inset shows position of the area in southern Atlantic Ocean.

It was observed from the shell measures of the 8 examined specimens of *A. flexispina* that the ratio height/width increases as the shell grows, suggesting a pattern of allometric growth (Fig. 5), probably a consequence of a gradual alteration in the angle of coiling in the species.

Arene flexispina appears to be related to *A. briareus* from the Caribbean and tropical western Atlantic, according to the original description (Dall, 1881:52), and later illustration by the same author (Dall, 1889: pl. 24, figs. 5, 5a), and by comparison of specimens (Col.Mol.MN 5390; Morg 14.969), mainly by its elevated spire and spinose ornamentation. *A. flexispina* differs, however, by its darker color, two obviously larger cords on body whorl, which are all about the same size or only a little larger than the remaining in *briareus*; ornamentation of the spiral cords consisting in about 11 large fluted spines, instead of about 40 small spines in *briareus*; a well differentiated ridge or cord around the umbilicus and a nodulose spiral ridge inside it in *briareus*, not present in *flexispina;* outer lip thicker in *briareus*.

Arene notialis from off southeastern Brazil differs by its whitish color, lower spire, about 21 nodules (not spines) on spiral cords in the body whorl, 8 joined strongly beaded basal spiral cords instead of 5 separated cords in *flexispina*; umbilicus smaller and straight, bordered by a larger basal cord and outer lip thicker in *notialis*, according to Marini (1975) and material examined of *A. notialis* from off Guarapari, Espírito Santo, Brazil, "N.Oc. Almirante Saldanha" col. September 1968, 80 m depth, Col.Mol.MN 4862, two specimens.

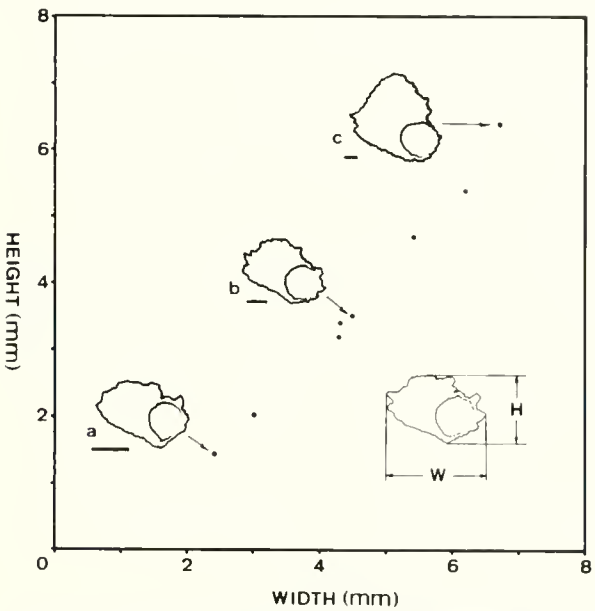


FIG. 5. Allometric shell growth in *Arene flexispina* n. sp.; sketches illustrate the shape of shells at three points on the curve: a) Paratype 7, Col.Mol.MN 5354, height 1.4 mm, width 2.4mm; b) Paratype 3, MORG 22807, height 3.5 mm, width 4.5 mm; c) Holotype, Col.Mol.MN 5352, height 6.4 mm, width 6.7 mm. Scale bars = 1 mm.

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AN EXCEPTIONAL STREAM POPULATION OF THE BANDED APPLESNAIL, *VIVIPARUS GEORGIANUS*, IN MICHIGAN

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ABSTRACT

SCUBA and a Surber sampler were used to study a stream population of Viviparus georgianus *(Lea). This locality, at the mouth of Runyan Creek where it flows into Hoisington Lake in Livingston County, Michigan, is only the fourth known locality for any species of* Viviparus *in that state. Densities were high (up to 864/m²) and varied significantly with gender (female > male), station type (reach > meander), and station position (upstream > downstream). Mean weight varied in the same ways with respect to gender and station type, but conversely for station position (whether downstream or upstream). The only effective interaction between factors was that between gender and station position: females decreased in size upstream faster than males. Weight–frequency data combined for all stations supported the independent measures of sex ratio (females > males) and sexual dimorphism in size.*

The main purpose of this paper is to draw attention to the fourth known population of *Viviparus georgianus* from Michigan. Voucher specimens have been deposited in the University of Michigan Museum of Zoology. The population thrives in Runyan Creek where it flows into Hoisington Lake in northern Livingston County. Here the stream is narrow (less than 6 m), steep-sided, and varies in depth from 85 to 156 cm as it meanders through an extensive marsh. The substrate is largely organic detritus contributed from marsh and stream plants (e.g., *Spartina pectinata, Scirpus lineatus, Typha latifolia, Nuphar variegatum, Lythrum decodon).* Our interest in this population derives from the rarity of this species in Michigan and from the very high densities found in a locality which must be very near this species' northern limits of distribution.

Since its discovery by two of our students, Donald House and Philip Davis, several papers have been published on the physiology of these snails (Fitch, 1975, 1976; Buckingham & Freed, 1976; Davis & Fenner, 1977; Studier & Pace, 1978). Ecological studies on this and related species include those of Van Cleave & Lederer (1932), Stanczykowska, *et al.* (1971, 1972), Burla (1972), Samochwalenko & Stanczykowska (1972), Young (1975), de Bernardi, *et al.* (1976), Brown (1978), Plinski, *et al.* (1978), Vail (1978), Imlay, *et al.* (1981), Jokinen (1982) and Thompson (1985). The main studies of the systematics and distribution of North American viviparids were those of Clench (1962) and Clench & Fuller (1965).

Materials and Methods

Many species of temperate, freshwater mollusks including *Viviparus*, move to deeper water, burrow into the substrate, and become less active during the Fall and Winter (Burla, 1972; Young, 1975). Therefore, when dredging and SCUBA assisted visual search methods have been used to collect these mollusks, this Fall migration has resulted in the undersampling of the population (Burla, 1972; Young, 1975; de Bernardi, *et al.* 1976). In narrow, steep-sided channels, however, this Fall migratory behavior serves to concentrate the population into the bottom detritus. Under these circumstances, the Fall may very well be the best single time of the year to study certain population characteristics.

During the last week of September, SCUBA, was used to collect three Surber samples (0.093 $m^2 \times 7.62$ cm) at each of 12 stations selected at the centers of consecutive stream meanders and reaches. Since samples were collected from

meanders and reaches whose radii and lengths varied considerably, stream channel distances between stations were not equal. The samples were taken from the deepest part of the stream cross-section with minor adjustments where water-lily rhizomes prevented forcing the sampler fully into the substrate. Everything within the frame was then scooped into the Surber net, brought to the surface, and transferred to labeled plastic containers for transport to the laboratory. In the lab, snails were sorted from the detritus, sexed, and then weighed on a top-loading balance to 0.01 g. Wet (live) body weight was used since Davis and Fenner (1977) showed its direct relationship to dry weight for these snails.

Results[1]

Total densities ranged from 151/m² to a maximum of 864/m². The average population densities were significantly higher in the reaches (608/m²) than in the meanders (534/m²). Closer examination showed that the average density of the males was the same in these two types of habitats (243:228/m²). The difference, therefore, was in the number of females (365:306/m²). While females outnumbered males in all stations combined (female/male = 1.42), the difference was greater in reaches (female/male = 1.50) than in meanders (female/male = 1.34). A comparison was also made between the six most downstream stations and the six most upstream stations. An average density of 462/m² was found for the downstream populations, while that of the upstream group was 680/m². Thus, the upstream populations were significantly denser than the downstream populations.

Live body-weight averages computed for each station (sexes combined) ranged from 0.75-1.97 g. The average size of the reach snails (1.57 g) was larger than that of the meander snails (1.35 g). Also, the average size of the females (1.90 g) was nearly twice that of the males (1.01 g). Furthermore, while the average size of both sexes decreased upstream, females decreased faster than males (Fig. 1).

Frequency distributions of weight classes for each sex were constructed for each station separately and for all stations combined. All curves for both sexes showed bimodal distributions of weight classes. Because the results were comparable for all stations, curves are provided only for the combined data (Fig. 2). We assume that size is at least roughly correlated with age (de Bernardi, *et al.*, 1976) and we will refer to the obvious groupings in Fig. 2 as cohorts.

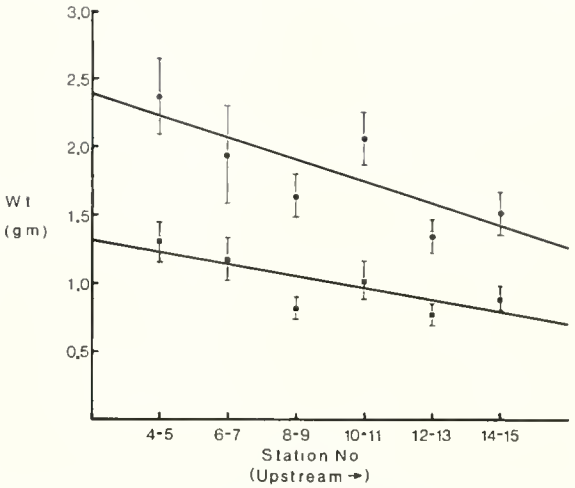

FIG. 1. Rates of change in male and female mean weights with stream position. Each point represents the mean of 20 meander and 20 reach snails selected randomly. The vertical bars represent +/− 2 Standard Errors. The curves are regression lines based on the mean weights for males and females separately. Females: Intercept = 2.378, Slope = -0.162. Males: Intercept = 1.308, Slope = -0.088.

The younger cohort for each sex had a mode at about 0.5 g, and ranged from 0.2-0.8 g for males and from 0.2-1.0 g for females. Females were slightly larger than males in this cohort, and outnumbered males 616 to 518. In the older cohort, 358 males weighed from 0.9-3.5 g, while 606 females weighed from 1.1-8.9 g. These curves, as well as the data already discussed indicate that the average adult female is nearly twice as large as the average adult male. Note also that there is no significant difference between the number of females in the two cohorts (616 & 606) and that in each, females outnumbered males (518 & 358). Finally, note that males were more numerous in the younger cohort than in the older one.

Discussion

As the papers by Clench (1962) and Clench & Fuller (1965) have documented, *Viviparus georgianus* (Lea) has apparently only invaded

[1]Readers wishing tabular data on density and mean weight distributions among the stations along with their statistical analyses may write the authors for copies.

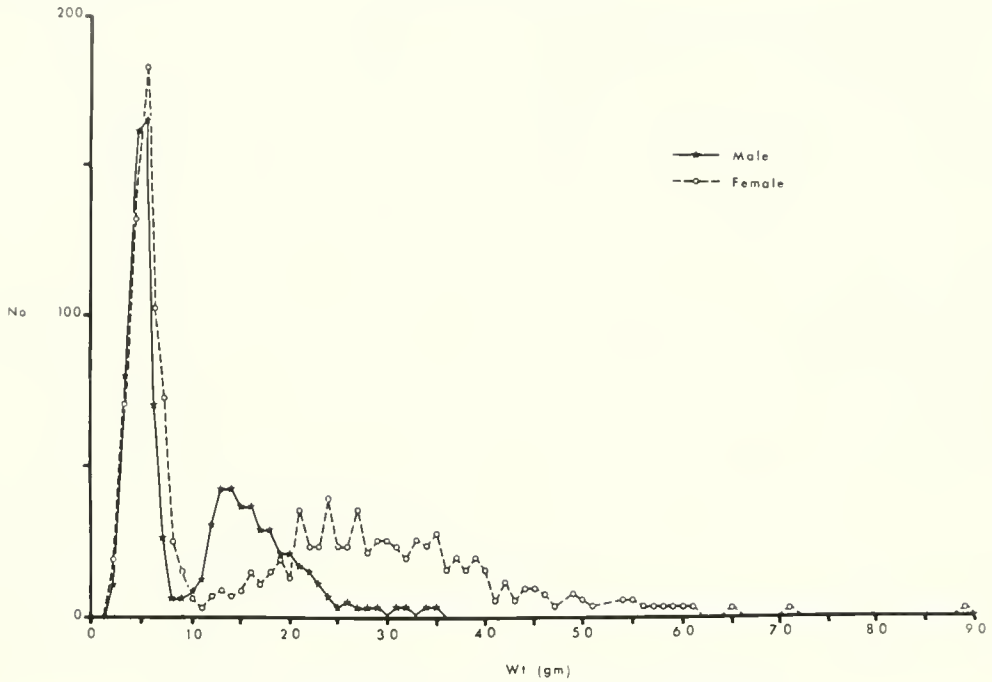

FIG. 2. Weight-frequency curves for all snails, sexes separate.

the northern states during the last century. Furthermore, Clench pointed out that only three localities are known from Michigan, and that these have been presented to the University of Michigan Museum of Zoology since the publication of Winslow's (1926) checklist of Michigan mollusks: UMMZ 166266 and 177214: Coguac Lake, 2 mi S.W. Battle Creek, Calhoun Co., Leslie Hubricht. Oct. 6, 1946; UMMZ 167226: Park N. of Owasso, Shiawassee Co., H. van der Schalie & Aurele LaRocque. July 10, 1947; UMMZ 173445: S. side Silver Lake, 15 mi N.E. Grand Rapids, Kent Co., C. D. Nelson. (No date recorded).

While it is possible that any specific locality may have long been populated and yet overlooked by collectors, it must be admitted that *Viviparus* is rare in Michigan. It is well-known that Michigan's molluscan fauna has long been among the best known in the world. Nevertheless, the above four lots of *V. georgianus* are in contrast to hundreds of lots of Michigan *Campeloma integrum* and *C. decisum* which fill 5 and 7 UMMZ cabinet drawers, respectively.

Not only is this one of the few Michigan localities for *Viviparus*, but it appears that among those so far reported, this locality most closely approaches this species' optimal habitat. This is supported by the fact that the population reached a maximum density of 864/m² and a maximum standing crop biomass (density × average live weight) of 1163 g/m². These data are higher than any yet reported for this species (Van Cleave & Lederer, 1932; Vail, 1978; Browne, 1978). Furthermore, these data exceed those for any freshwater snails (Hyman, 1967) and may prove to represent one of the largest standing crop biomass records among freshwater gastropods. These results are unexpected for a locality so near the northern limits of a species' range. The timing and method of collection must certainly have contributed to these high numbers (see *Materials and Methods*). The substrate in this habitat is very rich in organic detritus derived from the breakdown of the plants of the extensive marsh through which Runyan Creek slowly meanders. Earlier reports of a fine detritus habitat preference (Harman, 1972), and of combined detritus (Fretter & Graham, 1978) and filter (Cook, 1949) feeding methods by *Viviparus* species, provide some explanation for the optimal nature of this habitat. It certainly seems better suited to this species than its usually reported habitat "on the bottom

of mesotrophic or eutrophic lakes and ponds" (Browne, 1978). Indeed, at the mouth of Runyan Creek into Hoisington Lake, the density of these snails drops to less than one snail per square meter. The fact that these snails thrive in this detritus-rich habitat so near to their northern limits of distribution may indicate that food availability outweighs temperature or length of growing season in determining their optimal habitat.

Both sexual size dimorphism and disparate sex ratios have previously been recorded for northern populations of this (Van Cleave & Lederer, 1932; Browne, 1978) and other species of viviparids (Annandale & Sewell, 1921; van der Schalie, 1965; de Bernaardi, *et al.*, 1976; Vail, 1978). In Vail's (1978) Florida populations of *Viviparus georgianus*, however, sexual size dimorphism did not occur, and differences in sex ratios were not noted. Thus there seems to be both local and geographical variation in these sexual attributes. In our studies, variation in sex ratio could not be shown to be dependent on any of the following variables: station type (meander vs reach), station position (upstream vs downstream), water depth, water temperature, total density, or total biomass. Our large sample sizes, however, reduce the possibility that the variation is the result of sampling error. That these sexual differences are due to higher female growth rates and longer female longevity is suggested by our size-frequency data (Fig. 2) which support the findings of others (Van Cleave & Lederer, 1932; Browne, 1978). Because we made our collections in late September, our cohorts represent snails that had survived one growing season (about 4 months) and those which had survived at least two growing seasons and one winter (16-19 months). Some differential mortality (males > females) and differential growth (females > males) was evident by the end of the first growing season and increased substantially by the end of the second. That these differences are not due to differential numbers and size at birth is supported on both factual and theoretical grounds. Van Cleave and Lederer (1932) found that the two sexes were present in equal numbers at birth. Fisher showed long ago that this is to be expected if there is no sexual difference in energy costs (*i.e.*, no difference in size) of the progeny to the parent (Pianka, 1974). Brown (1978), on bioenergetic and anatomical grounds suggested that "selection probably drives females toward a larger size than males as a consequence of the cost of viviparity." Furthermore, Browne pointed out that males have two options in dividing their energy resources. Evidently, some males devote much of the first year in feeding and survival, with most reproductive effort delayed until the second growing season. Other males might spend most of their time and energy actively seeking females while spending relatively less time feeding. While the latter were characteristic of Browne's populations and would generally be expected to leave more progeny, variation in such strategies could account for some of the variation in the distribution of sexual differences in size and number.

The fact that these snails are larger and more numerous in reaches than in meanders seems more easily testable. Higher currents in the meanders may reasonably be expected to remove both young snails and detritus and deposit them in the reaches. Even if the current rarely displaces snails, the cumulative effect of erosion and deposition on habitat enrichment in the reaches could account for the differences in snail density and biomass. Analysis of the variation of the current velocity and sediment load between habitat types and between seasons would be very helpful in answering these questions.

It is perplexing that density and biomass increase upstream while mean weights decrease (see *Results*). Since biomass increases upstream we might inquire whether the carrying capacity (*e.g.*, as determined by food availability) increases upstream, or whether the upstream populations are more efficient in filling their niche. The first seems a more testable question. Because upstream populations are denser but individuals are smaller, we may ask whether or not these snails are stunted as a result of crowding (*i.e.*, intraspecific competition). Also, the larger size but lower density of the downstream snails may indicate that while some extrinsic factor controls numbers, surviving snails have ecological room for growth (*i.e.*, crowding reduced). Higher predation pressure on small downstream snails could account for such population characteristics. The seasonally dense

populations of ducks and geese on Hoisington Lake and the possibility of lake fish foraging some distance upstream could provide the gradient in predation pressure. The importance of ducks as mollusk predators is well known (Malone, 1965; Thompson, 1973). de Bernardi *et al.* (1978) attribute substantial modification of population structure to predation by ducks, and Price (1957) has shown the importance of lake fish predation on viviparids. Small snails with their weaker shells would be subject to higher predation rates than large snails. In other words, snails that survive to a certain size have escaped a major source of mortality (*i.e.*, predation). These snails, relatively few in number, would not be subjected to high intraspecific competition and would grow to a relatively large size. That stunting is occurring upstream might also be inferred from the fact that females get larger faster than males as we sample further and further downstream. Since females seem to have higher growth rates and greater reproductive energy requirements (because of viviparity), they may be more easily stunted in the more crowded upstream habitats. Conversely, under conditions of lower density and presumed higher detritus deposition downstream, females may be freer to express their genetically determined faster growing rates. The above speculation obviously suggests a variety of future studies. These would include analyses of the relative organic content and depth of sediments in the different stream habitats. In addition, it would be beneficial to observe the feeding behavior of potential predators, and to actually examine their stomach contents. Furthermore, predator and competitor exclusion pens could be set up in the various habitats to test the actual effects of these factors. Finally, laboratory and field growth experiments would be invaluable in testing our hypotheses.

Acknowledgments

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MODERN METHODS USED TO AGE OCEANIC BIVALVES

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ABSTRACT

Modern techniques of thin-sectioning chondrophores and the preparation of acetate peels of sectioned valves are described that expose internal age/growth structures of two commercially important U.S. oceanic bivalves, Spisula *and* Arctica. *The application of the methods in specific studies is reviewed. Verification of annual age marks was based on mark-recapture experiments and length frequency analyses for both species.*

New methods have been under investigation by the Northeast Fisheries Center since the mid-1970's for determining the age and growth characteristics of the Atlantic surf clam, *Spisula solidissima* (Dillwyn), and ocean quahog, *Arctica islandica* (Linné), bivalves that supply the bulk (79% in 1983) of the meats for clam production in the United States. Goals of the investigation were that the methods produce accurate age determinations and be efficient, since about 1,500 shell specimens of each species may be taken during annual surveys. Age determinations on a timely basis are specifically needed for evaluations of age composition in assessment studies of the populations.

Bands or rings form annually on the external valve surface of some bivalves, much like rings found in tree trunks, and have been used to determine age (Lutz and Rhoads 1980). Similar bands appear on the valves of young surf clams and ocean quahogs up to about 15 years of age, but with increasing age and size the earlier bands are often obliterated by erosion and later

bands become too crowded together at the valve margin for definite separation, even under microscopic examination. Confusing, unverifiable and incomplete records are inevitable when such poorly defined shell features are used for age analysis. Thus, the use of such a general method for critical studies is precluded by the lack of accuracy in age determinations.

Specific internal shell deposits that form annually have been found in other bivalves (Lutz and Rhoads 1980). They are considered to be relatively unaffected by external conditions causing erosion, but require care in exposing the deposits and critical microscopic examination. Therefore, methodologies were developed for examining such deposits in the shells of surf clams and ocean quahogs.

Surf Clam Method

Preliminary examinations of internal age/growth features in the valves of surf clams were begun in 1975. Such examinations seemed justified by the presence of thin, dark lines seen alternating with broader, white growth increments in fossilized valves. Whole surf clam valves were cut in about one-half hour from the beginning (umbo) to the end of a clam's life at the valve margin using a diamond-impregnated saw blade (Fig. 1). The cut edges were then polished to remove saw marks and enhance the distinctive dark lines that were suspected to be age annuli. These lines curved down and back toward the umbo of a valve and became increasingly attenuated at the myostracal layer from a more prominent beginning beneath external bands. The myostracal layer separated inner and outer shell layers in these valves. The lines were validated as annual age marks by marking some surf clams for release and recovery at Chincoteague Inlet, VA (Ropes and Merrill 1970; Jones *et al.* 1978). Ambrose *et al.* (1980), Jones (1980, 1981a and b, 1983), Jones *et al.* (1983), and Arthur *et al.* (1983) report studies based on the annual periodicity of these lines in surf clams.

Age determinations of whole valves required careful microscopic examination of the cut surfaces. Holding the valve level and in focus under the microscope proved difficult and even more frustrating when trying to make growth measurements. In addition, the cutting, polishing and

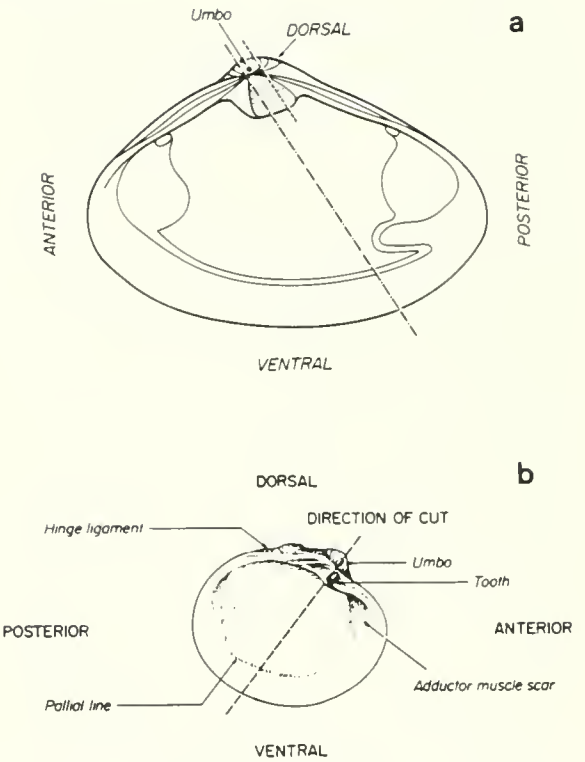

FIG. 1. Sketches of internal valve features and direction of cut (dashed line) (a) to remove part of the chondrophore (lightly stippled area) from a surf clam, *Spisula solidissima*, (from Ropes and O'Brien 1979), and (b) to completely section the left valve of an ocean quahog, *Arctica islandica*, and a unique hinge tooth bearing age lines (from Ropes 1982).

examination procedures required about one hour per specimen and were considered to be excessively time consuming. Nevertheless, growth lines in the valves were clearly exposed and this was a necessary procedure used in establishing a basis for a more efficient method to follow.

Ropes and O'Brien (1979) developed a new method of exposing age lines in a part of the hinge called the chondrophore (Fig. 1). This portion of the shell can be cut in less than a minute using two diamond-impregnated saw blades spaced 2 mm apart and is then easily broken away from the shell by finger pressure. The piece is glued onto a glass slide for thin-sectioning, which usually takes less than 15 minutes and results in about a 0.25-mm-thick slice. Age lines in the thin section are translucent when viewed with transmitted light; growth increments between the lines are opaque. In photographic enlargements the translucent lines appear as dark lines and are

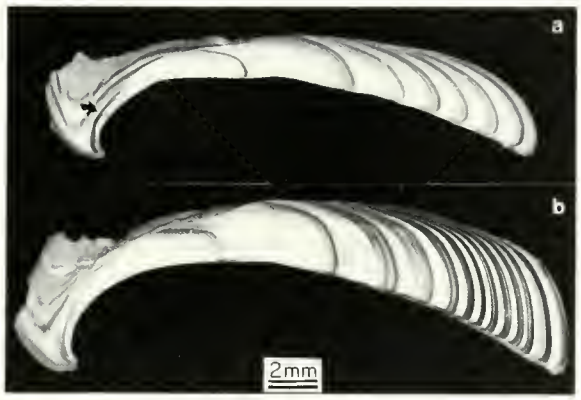

FIG. 2. Photographic enlargements of thin-sectioned chondrophores from surf clams: (a) 8 years old and 139 mm in shell length; and (b) 13 years old and 137 mm in shell length. The first annulus formed in the life of a surf clam is sometimes faint (an arrow points to a bold one in the chondrophore of clam a). The most recent annulus at the marginal edge of these chondrophores was not completely formed.

the annuli (Fig. 2). Linear measurements from the umbo to growth bands in the chondrophore regressed upon the valve length of corresponding external bands for a sample of surf clams, using least squares technique, resulted in a relatively high correlation coefficient ($r = 0.97$). The regression equation ($y = 22.739 + 59.063 \times$) accounted for 94% of the variation between the two measurements. Thus, annuli in the chondrophores of surf clams correspond in number and relative location with those in the valve. This refinement of the basic method of exposing internal age lines in surf clams produces consistent age determinations, measurements of growth throughout the life of a clam, and records for future reference.

Ocean Quahog Method

Age determinations of ocean quahogs were significantly advanced by the recommendations of Thompson *et al.* (1980a and b) and Jones (1980) that the acetate peel technique be used. In the technique developed at the NEFC, Woods Hole Laboratory, left valves are routinely used because they have a unique, single tooth containing valuable age information useful in confirming counts made from the valve. The steps in preparing valves include sectioning (Fig. 2), bleaching to remove the thick periostracum, embedding in epoxy, polishing, and etching the cut surface with a 1% HCl solution (Ropes 1982). Then sheet acetate is applied with acetone to melt the acetate and peel off after the acetone completely evaporates. Except for the one minute etching period, the sectioning (15-30 min), embedding (overnight hardening), polishing (2-3 hr) and drying (1 hr) periods are time consuming. The production of a peel is necessary, since the thin age annuli are microscopically indistinct on the external valve surface or in the cut surface of an ocean quahog shell.

Although age annuli and growth increments are reproduced much more clearly in a peel than in the cut surface of the shell, it must be examined microscopically and the many crowded annuli in old quahogs are a challenge to count. It is not unusual to have quahogs that are about 100 years old.

Various experimental evidence suggests that annuli are formed in the shells of ocean quahogs (Thompson *et al.* 1980a and b, Jones 1980) including the use of radiometric techniques (Turekian *et al.* 1982, Bennett *et al.* 1982). A NMFS marking experiment substantially supported such a hypothesis. Specimens were marked for release and recapture at a 53 m deep site off Shinnecock Inlet, Long Island, NY. The marks were made by two carborundum discs spaced 2 mm apart and mounted on an electric grinder. This produced distinctive parallel grooves at the ventral edge of about 42,000 clams released in 1978. Marked quahogs have been recovered annually thereafter.

Murawski *et al.* (1982) developed a growth rate relationship for marked ocean quahogs (59-104 mm in shell length) recaptured one year after release ($SL_{t+1} = 2.0811 + 0.9802\ SL_t$). Back-calculated growth measurements at age of unmarked quahogs (19-60 mm in shell length) captured in the vicinity of the marking site resulted in an age/growth relationship for younger, smaller specimens [$SL = 75.68\text{-}81.31\ (0.9056)^t$]. Growth in length described by these equations provided additional evidence for the growth rate of the species at the Long Island site.

Ropes *et al* (in press) found definite prismatic microstructures, considered to be the basis for the formation of annuli, that separated growth increments of predominantly homogenous microstructures. Although the microstructures are only visible by scanning electron microscopy, light microscope examinations of acetate peels

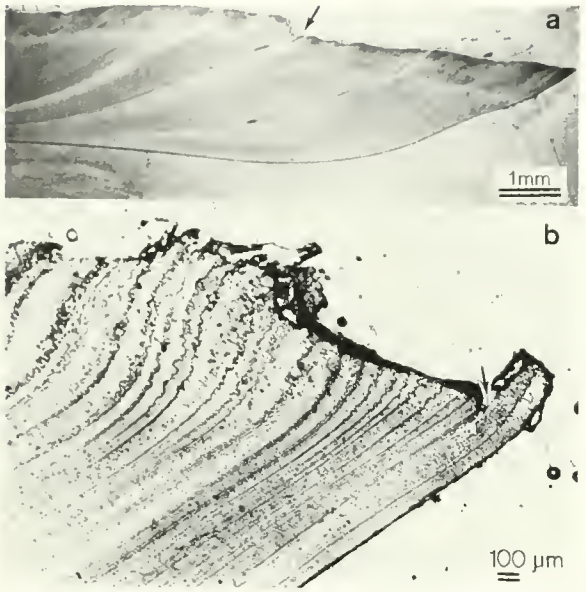

FIG. 3. Photomicrographs of acetate peels showing growth and annuli at the valve margins of ocean quahogs marked for release off Long Island, NY, in 1978 and recovered two years later. (a) a 15-year-old, 60 mm in shell length clam, and (b) a 95-year-old, 92 mm in shell length clam. An arrow points to an annulus formed soon after marking. Only one additional annulus was formed thereafter by both clams, and it separated two increments of shell growth accreted after marking. The flattened area in (b) was produced by the notching operation.

clearly revealed the annual periodicity of annuli in small and large marked quahogs (Fig. 3).

General Comments

The growth of ocean quahogs is characteristically slow except during the first 20 years of life (Fig. 4). Quahogs of about 100 mm in shell length are about 100 years of age and are common in the population. Maximum shell length approaches 140 mm, but large size may not indicate very old age (Ropes and Murawski 1983). A specimen 107 mm long has been found to have a minimum of 221 growth lines in its valve and it was alive when caught. A longevity of at least 225 years surpasses known estimates for other bivalves. Ropes and Pyoas (1982) found evidence for geographic variation in the growth of ocean quahogs. Quahogs from Georges Bank were younger than specimens of equal length from off Long Island, NY, or off Sable Island, Canada. In a comparison of growth data for Georges Bank quahogs with marked quahogs from off Long Island, a much slower rate was

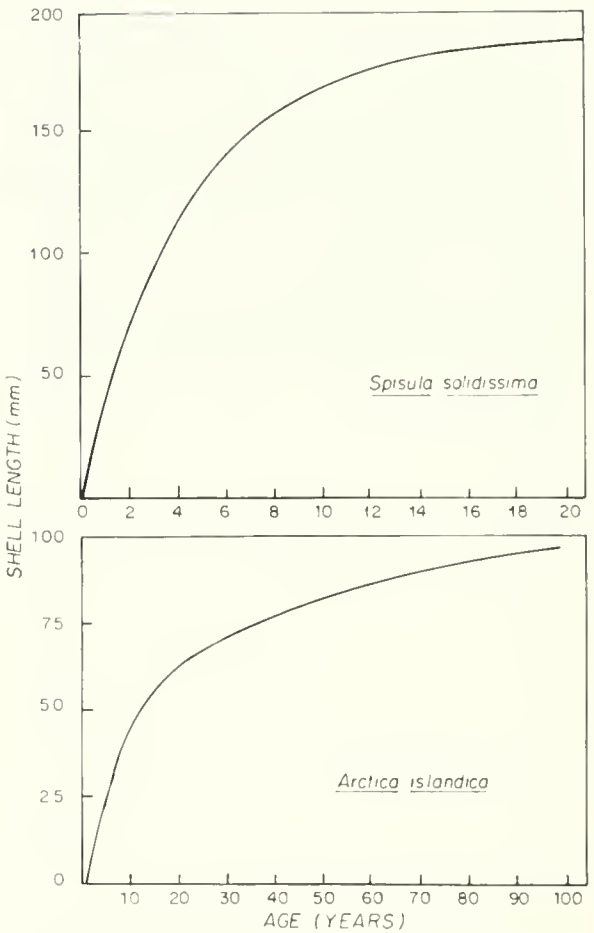

FIG. 4. General age (in years) and growth relationship for surf clams (*Spisula solidissima*) (Ropes 1980) and ocean quahogs (*Arctica islandica*) (Murawski *et al.* 1982).

obtained for the latter area. Ocean quahogs appear to be reproductively viable throughout the long life span (Thompson *et al.* 1980a). Ocean quahog growth contrasts sharply with the faster growing surf clam. It commonly attains a shell length of about 165 mm in 10 years (Ropes 1980). The maximum recorded shell length of a surf clam is 226 mm and longevity is estimated to be about 35 years. Growth lines similar to those in *S. solidissima* were found in Stimpson's surf clam, *S. polynyma*, another species in the family Mactridae. This suggests that the method of preparing surf clams for ageing may have application for other species with well developed chondrophores. Surf clams are probably also reproductive throughout their life span. Spawning has been implicated as the possible stimulus for deposition of growth lines in both species

(Thompson *et al.* 1980a, Jones *et al.* 1978).

Population assessment studies integrate ageing of large numbers of specimens throughout the extensive distribution of both species in the Middle Atlantic Bight and off New England. Samples of surf clam shells for age analysis are routinely taken during annual surveys of the resource in the Middle Atlantic Bight and off New England. The refined method serves efficiently in processing the samples collected during a survey without sacrificing accuracy of age determinations. The age data provide valuable information on growth rates and age composition in assessment studies of this important commercial bivalve. The collection of similar data for ocean quahogs is thwarted by the labor intensive nature of shell preparation and microscopic examination. Nevertheless, ocean quahog samples from localized areas are under investigation to gain insight into the age/growth phenomena. Age data are an integral part of management plans regulating both resources that have been developed by the Mid-Atlantic Fishery Management Council.

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TWO NEW SPECIES OF *FAVARTIA* FROM THE WEST PACIFIC OCEAN (GASTROPODA: MURICIDAE)

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ABSTRACT

Two new species of muricids, Favartia (Murexiella) rosamiae *and* F. (M.) leonae *are described from the Philippines and Ryukyu Islands, and compared with related species.*

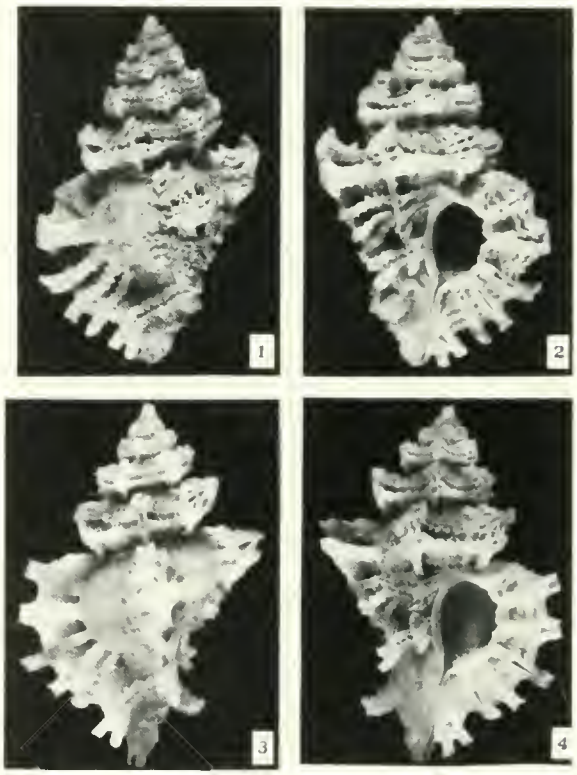
Through the courtesy of several shell collectors, we have recently obtained for the collection of the San Diego Natural History Museum, specimens of two undescribed species of muricid gastropods. One of the new species, *Favartia (Murexiella) rosamiae* has been confused with *F. cyclostoma* (Sowerby, 1841). The redescription of *F. cyclostoma* and selection of a lectotype was discussed by D'Attilio and Myers (1984).

Institutional abbreviations used in this paper are: AMNH = American Museum of Natural History, New York, New York, and SDNHM = San Diego Natural History Museum, San Diego, California.

MURICIDAE Rafinesque, 1815
MURICOPSINAE Radwin and D'Attilio, 1971
Genus *Favartia* Jousseaume, 1880
Subgenus *Murexiella*
Clench and Perez Farfante, 1945

Favartia (Murexiella) rosamiae
new species
Figs. 1 to 6

Shell moderately broad, fusiform; spire elongate; five to six postnuclear whorls; shoulder angulate on spire; suture impressed. Protoconch of holotype eroded; protoconch of paratype B with three and one-quarter conical transparent whorls. Aperture subovate; outer lip crenulate and fluted; inner lip moderately erect anteriorly. Anal sulcus weakly defined. Siphonal canal long, narrowly open, broad above, tapering terminally, recurved and tube-like. Two to four well-preserved former canal terminations on the siphonal fasciole. Four varices on body whorl, five on penultimate whorl; body whorl varices thick, beginning at suture above shoulder and descending anteriorly to the canal. Spiral sculpture consisting of six strong cords terminating in spines; one or two cords above the shoulder, the strongest cord and spine at the shoulder and three secondary cords



FIGS. 1 and 2. *Favartia (Murexiella) rosamiae* D'Attilio and Myers. Dorsal **(1)** and apertural **(2)** views of holotype. Dimensions 17.7 mm × 12.2 mm. SDNHM 80742.

FIGS. 3 and 4. *Favartia (Murexiella) rosamiae* D'Attilio and Myers. Dorsal **(3)** and apertural **(4)** views of paratype A. Dimensions 15 mm × 10.7 mm. SDNHM 85101.

FIG. 5. Camera lucida drawing of the protoconch of *F. (M.) rosamiae*, paratype **B**. SDNHM 82288. Greatly enlarged.

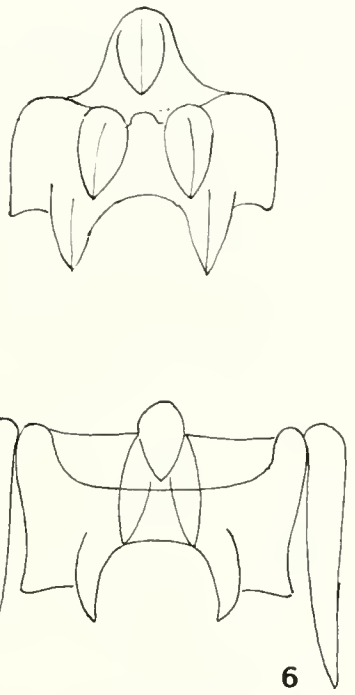


FIG. 6. Detail drawing of the radula of *F. (M.) rosamiae*. Greatly enlarged.

below. Two additional cords on the canal. Cords separated on the dorsal side by a strongly depressed or excavated area. Cords covered by blunt appressed scales; a portion of each scale bulges beyond the width of the cord lending the cord a toothed or serrated appearance on both anterior and posterior sides. Cords and spines on the outer lip connected by a flange and the spiny extension of the spiral cords terminate well beyond the flange. Intervarical areas on the body whorl broadest between the final varix and the preceeding one. The scabrous cords strong on the varices and obsolete on the final intervarical area. Cords and scales microscopically spirally grooved with the terminal portion of the scales convexly scalloped. The radula ribbon long and narrow with about 110 rows of teeth. The rachidian plate with five strongly projecting, stocky short cusps, the central cusp extending above the rachidian plate.

Color: Holotype – dull white with four narrow brown bands visible within the aperture; siphonal canal a pale-orange. Color variability noted as follows: creamy white to tan occasionally with broad brown or red bands exteriorly. The siphonal canal either white or tan, occasionally orange or deep coral-red.

Type Locality: Cebu, Bohol Straits, Philippine Islands, 75-100 meters depth. Paratypes from Balut Island, Mindanao, Philippine Islands; Cebu, Bohol Straits, Philippine Islands; Okinawa, Ryukyu Islands, Japan. Collected in 1984,.

Dimensions: Holotype 17.7 mm in length, width 12.2 mm from Cebu, Bohol Straits, Philippine Islands (SDNHM 80742); paratype A, 15 mm×10.7 mm from Okinawa, Ryukyu Islands, Japan (SDNHM 85101); paratype B. 8.8 mm× 6.2 mm from Cebu, Bohol Straits, Philippine Islands (SDNHM 82288). Seven paratypes from Cebu, Bohol Straits, Philippine Islands (SDNHM 80742) with the following measurements: 13.5 mm×10.4 mm; 13.8 mm×9.0 mm; 13.4 mm×9.7 mm; 12.1 mm×8.0 mm; 10.5 mm ×7.3 mm; 10.2 mm×7.3 mm; 9.5 mm×6.2 mm. Twelve paratypes from Okinawa, Japan (SDNHM 81639) with the following measurements: 15.7 mm×11.3 mm; 13.4 mm×9.8 mm; 12.1 mm×9.0 mm; 12.4 mm×8.5 mm; 11.1 mm ×9.6 mm; 12.1 mm×8.6 mm; 11.6 mm×7.7 mm; 11.3 mm×8.5 mm; 11.5 mm×7.1 mm; 11.5 mm×7.7 mm; 10.6 mm×8.5 mm; 9.8 mm×7.6 mm. Twelve paratypes from Balut Mindanao Island, Philippine Islands (SDNHM 84345) with the following measurements: 12.3 mm×8.4 mm; 12.7 mm×7.5 mm; 12.5 mm×8.3 mm; 11.8 mm ×8.2 mm; 12.3 mm×7.5 mm; 11.5 mm×8.3 mm; 11.5 mm×8.4 mm; 11.3 mm×8.0 mm; 10.7 mm ×7.6 mm; 10.8 mm×7.7 mm; 11.3 mm×7.5 mm; 11.3 mm×8.5 mm.

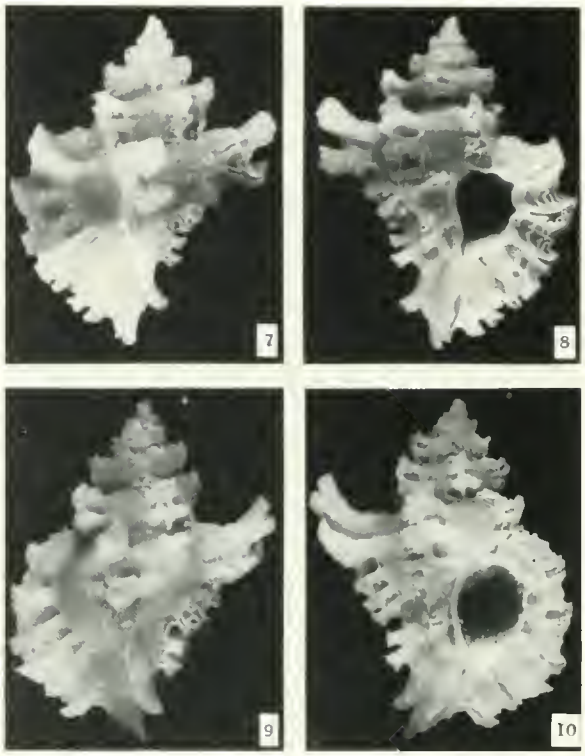
Two paratypes from Cebu, Bohol Straits, Philippine Islands are deposited in the American Museum of Natural History (AMNH 213556). We are depositing two paratypes each in the following institutions: two paratypes in the

Academy of Natural Sciences of Philadelphia, from Cebu, Bohol Straits, Philippine Islands, 14.3 mm×9.0 mm; 13.3 mm×8.6 mm; two paratypes in the U. S. National Museum, from Cebu, Bohol Straits, Philippine Islands 13.4 mm×7.4 mm; 10.7 mm×8.8 mm; two paratypes in the Los Angeles County Museum from Balut, Mindanao Island, Philippine Islands 12.7 mm×9.2 mm; 12.1 mm×8.1 mm; two paratypes in the British Museum (Natural History) from Balut, Mindanao Island, Philippine Islands 14.5 mm ×11.0 mm; 12.5 mm×9.2 mm.

Etymology: This species is named for Rose D'Attilio, wife of the senior author, who first introduced him to seashells by sending him a box of shells from Florida in 1938. The Italian "rosa mia", which means my Rose, is latinized into the genitive form ending.

Discussion: Comparison is made with *Favartia cirrosa* (Hinds, 1844), the shell of which is broader with a shorter spire and possesses numerous strong lirations within the aperture; the varices are sharply recurved and number six on the body whorl, eight on the penultimate whorl, and nine on the whorl preceding the penultimate whorl. This increase in the number of varices on the moderately short spire tends to obscure the suture. The spire is higher and better defined in *F. rosamiae*, and the varices on the body whorl number four or five. The protoconch of *F. cirrosa* consists of two and one-half whorls, both whorls being the same diameter, while the protoconch of *F. rosamiae* consists of three and one-quarter smooth conical transparent whorls. For further discussion of *F. cirrosa*, a rare, long poorly-known species, see D'Attilio (1981).

This new species has been confused with *F. cyclostoma* (Sowerby, 1841). The well-defined characters of *F. cyclostoma* have been treated by D'Attilio and Myers (1984). Based on the morphology of the syntypic material, *F. cyclostoma* has a broader, heavier shell, the lectotype of which measures 24 mm×17 mm.



FIGS. 7 and 8. *Favartia (Murexiella) leonae* D'Attilio and Myers. Dorsal **(7)** and apertural **(8)** views of holotype. Dimensions 14.2 mm×11.5 mm. SDNHM 81638.

FIGS. 9 and 10. *Favartia (Murexiella) leonae* D'Attilio and Myers. Dorsal **(9)** and apertural **(10)** views of paratype **H.** Dimensions 13.1 mm×10.6 mm. SDNHM 85109.

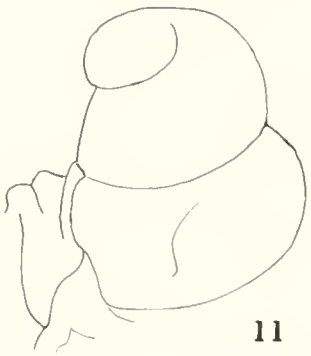


FIG. 11. Camera lucida drawing of the protoconch of *F. (M.) leonae* paratype **D.** SDNHM 85105. Greatly enlarged.

Favartia (Murexiella) leonae, new species

Figs. 7 to 11

Shell broadly fusiform, shoulder angulate, spire moderately high, suture impressed. Protoconch of holotype eroded; protoconch of paratype D with 2¼ dull white blunt, convex whorls; four to five postnuclear whorls. Aperture white, ovate; inner lip erect anteriorly. Anal sulcus directed to the left. Outer lip erect, crenulate, reflecting the exterior spiral sculpture. Siphonal canal broad above, narrowing and recurving distally, and weakly open. Siphonal fasciole with three scaly tubelike remnants of earlier canal terminations. Four varices on body whorl with

the intervarical areas unequal. Five varices on penultimate whorl. Two weak spiral cords on spire strongly developed only on the back slope of the varix. Five to seven spiral cords on body whorl, weakly defined between varices and strongly developed on receding portion of the varices. The first two to three cords developing into elongate spines on the varices except on the apertural varix where all cords are of equal size. On the final varix the moderately projecting cords connected by a continuous flange which abuts the penultimate whorl. Growth striae on the body whorl weakly developed. The leading side of the apertural flange with about four to seven well developed lamellae in the interspaces between the cords.

Color: Pale rose shell with spines a much lighter hue. Occasionally (holotype) with a broad band of deep coral red.

Type locality: Bolo Point, Okinawa, Ryukyu Islands, Japan from 55 meters depth. Paratypes from Okinawa, Ryukyu Islands, Japan, and from Bohol Straits, Philippine Islands.

Dimensions: Holotype 14.2 mm in length 11.5 mm in width from Okinawa, Japan, (SDNHM 81638); paratype A, 14.4 mm×10.2 mm from Okinawa, Japan (SDNHM 85102); paratype **B**, 10.7 mm×8.6 mm from Okinawa, Japan (AMNH 213555); paratype **C**, 12.5 mm×8.7 mm from Okinawa, Japan (SDNHM 85104); paratype **D**, 11.1 mm×7.8 mm from Bohol Straits, Philippine Islands, (SDNHM 85105); paratype **E**, 14.3 mm× 10.7 mm from Okinawa, Japan, (SDNHM 85106); paratype **F**, 14.2 mm×11.0 mm from Okinawa, Japan, (SDNHM 85107); paratype **G**, 14.0 mm× 9.8 mm from Okinawa, Japan, (SDNHM 85108); paratype **H**, 13.1 mm ×10.6 mm from Okinawa, Japan, (SDNHM 85109); paratype **I**, 12.5 mm× 9.2 mm (SDNHM 85110).

Etymology: Named for Leona Bellin, wife of Phillip Bellin, who first collected specimens of *Favartia (Murexiella) leonae* from Okinawa, Ryukyu Islands, Japan, used in this study.

Discussion: This species bears little comparison with any of its congeners, with the exception of an unnamed species which is more widespread and of a larger size, under study at the present time from the western Pacific. The lack of shoulder spines on the apertural varix is a consistent character in the specimens studied.

Acknowledgments

We wish to thank the following friends who contributed specimens for our study: Phillip Bellin of Okinawa, Japan; Robert Yin of La Jolla, California; Donald Pisor of San Diego, California; Edward Swoboda of Los Angeles, California; Robert Foster and Charles Glass of Santa Barbara, California. We are grateful to David K. Mulliner for the photography used in this paper and Dr. Hans Bertsch for his assistance with the Latin orthography. Dr. William K. Emerson (AMNH) kindly reviewed the manuscript.

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A RAPID METHOD FOR SLIDE MOUNTING OF MINUTE RADULAE, WITH A BIBLIOGRAPHY OF RADULA MOUNTING TECHNIQUES

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ABSTRACT

A method for rapidly cleaning, staining and mounting many minute radulae is detailed through the use of many-chambered, deep-well slides, together with the use of CMC as a combined stain/mounting medium. A bibliography of literature on mounting radulae for both light and scanning electron microscopy is provided.

Previous methods for preparing radulae have generally dealt with fairly large or macroscopic radulae. Most methods (e.g., Bowell, 1915; Gascoigne, 1975; Meeuse, 1950; Radwin, 1969) involve multiple handlings of the radula, i.e., cleaning, rinsing, possibly several steps of staining, and bringing it up through a series of solutions prior to preparation for mounting. However, these methods are inappropriate and time-consuming for extremely minute radulae, and most often result in their loss.

The simplest methods for mounting very small radulae have been those accomplished on a single microscope slide. Such methods were suggested by Binney (1885:45), Beecher (1888:11), Verdcourt (1946), Meeuse (1950a:36), and later by Turner (1960), and Basch (1961). However, this procedure requires that each radula be processed individually and consecutively, requiring much time to process several radulae.

The method described herein has two advantages: (1) many radulae can be processed at nearly the same time, and (2) loss of extremely minute radulae is avoided by handling each radula only once, with the use of "CMC" (unabbreviated spelling unknown) as both a stain and a mounting medium. Although use of CMC for mounting radulae is not new, it has apparently not been published, and is known primarily to more established malacologists. Advantages of the medium have been detailed for use with snail genitalia (Michelson, 1960), larval trematodes (Davis, 1964), and for larval chironomids (Beckett and Lewis, 1982).

A bibliography of radula mounting techniques for both scanning electron and optical microscopy is provided.

Materials and Methods

CMC is a non-resinous, water-miscible mounting medium available from Masters Chemical Company, Inc., P.O. Box 2382, Des Plaines, Illinois 60018. Of the two types of mounting media offered, the faster-drying "CMC" series is highly preferable over the slower-drying "CMCP" series, for purposes described herein. The media may be obtained in a high or low viscosity state, with refractive indices ranging from 1.38-1.40 (see E.P.A., 1980). The material is available pretinted with stain (aniline blue or acid fuchsin) or colorless, to which one can add his own stain if desired.

To dissolve all soft tissue, the entire animal or only the odontophore of the animal (depending on specimen size) is soaked for a day in 5-10% NaOH placed in one marked well of a multi-well Boerner slide (available through American Scientific Products, 1430 Waukegan Rd., McGaw Park, Illinois 60085), or similar product. By utilizing all of the wells of the Boerner slide, many radulae can be prepared simultaneously. Heating to accelerate the dissolving process is disadvantageous because (1) excess heat may adversely affect the radular structure (see: Lindberg, 1977) and (2) high heat or boiling usually causes varying degrees of flocculent material to form in the NaOH, thus hindering the relocation of extremely small radulae.

The Boerner slide is then placed in a container with a tight-fitting lid, into which has been placed a paper towel moistened with water, thus creating a humidity chamber which prevents the fluid in the Boerner slide from evaporating. The specimens are usually left to soak overnight, but may be left several days. Slight warming would accelerate the dissolving process.

At the completion of the dissolving process, a radula is then located on the Boerner slide, using a dissecting microscope. A toothpick or other small probe is dipped into the stained CMC, removed, and the excess allowed to drip back into the bottle. The probe is then touched to a clean microscope slide to apply a very small portion (much less than a drop) of CMC. With an extremely fine dissecting needle type of probe in each hand, the radula is teased off the bottom of the well and brought to the surface. The radula is always manipulated by placing the probe(s) under the radula and lifting; the radula is never pinched with forceps or other tools. The microscope is pre-focused to the fluid surface, or re-adjusted if necessary.

The radula is guided onto the upper surface of a submerged probe tip, using another probe as a guide. The radula is then lifted out of the NaOH and held stationary, directly above the well. The Boerner slide is moved aside, and the microscope slide is positioned such that the CMC on the slide is directly under the held radula, both within the field of view of the microscope. The radula and focus are lowered simultaneously such that one can see when the probe tip and radula contact the CMC. When contact is made, the second probe is used to ease the radula off the first probe, if necessary, and into the center of the CMC.

At this point, the procedure varies somewhat for larger (but still small) radulae, and those which are extremely small:

(A) With larger material and with the radula now in a very small amount of CMC, it can be manipulated, flattened, distorted, or dissected. As the CMC begins to set, the radula (or portions of it) can be placed in final position and allowed to dry until quite firm. Should the CMC begin to set prematurely, one has but to add a very slight amount of water to the preparation to gain more time. The CMC may turn slightly opaque, but should clear fairly rapidly. A full drop of stained CMC is then placed on the center of a clean cover slip which is picked up and inverted to form a "hanging drop" of CMC on the underside of the slip. The slip is then very slowly (to avoid bubble formation) placed onto the slide and radula. As an alternative, additional CMC may be applied to the dry or nearly dry mount (to fill depressions in the set CMC) and the cover slip applied dry.

(B) Very small radulae cannot be manipulated at this time, and should be kept wet (see below), in a somewhat larger drop of CMC. In this case, the cover slip may be applied dry, or with a hanging drop of additional CMC. As the CMC flows into position under the weight of the cover slip, the smaller radula (if allowed to remain wet) can be manipulated and kept toward the center of the cover slip by applying slight pressure on the edge of the cover slip toward which the radula is traveling.

The radula is usually examined immediately, and the number of radular rows are usually counted at this time. Using low power of a compound microscope, the desired location and orientation of the still wet, smaller radula can be attained by slight pressure on the cover slip. Extreme pressure will cause the teeth to separate from the radular membrane (which is often desirable). Proper movement of the cover slip, and/or prior manipulation, can attain a final mount which has the radula partially folded over itself and/or twisted, possibly with several teeth dissociated from the radular membrane. This reveals many different angles of the teeth, and gives an observer the maximum information from a slide mount . . . much more than if the radula were simply flattened. The above mounting procedure is then repeated for the remaining radulae. Because the CMC does not dry rapidly, once the cover slip is applied, several radulae may be mounted on slides prior to examination of them with a compound microscope; i.e., they can be processed in small groups to conserve time.

With the radula in the proper position, and with all movement of the radula and CMC ceased, the slide is further examined with higher magnification and/or allowed to dry for about 24 hours. At that time, the dried, excess CMC is trimmed away with the aid of a scalpel (a curved blade is preferable). Final cleaning is ac-

complished by wiping with a moist, lint-free tissue. This trimming and cleaning is not only cosmetic, but also provides clean surfaces to allow a good "ringing" bond. The edge of the cover slip is then sealed or "ringed" with clear nail polish or other sutiable substance, twice, to insure a good seal such that the mounting medium will not evaporate.

Stains

Any suitable stain may be added to the colorless CMC. The more desirable stains used have been acid stains, Acid Fuchsin and Lignin Pink. Pronticil dye works well (pers. comm. Joseph Rosewater, 1984) and was used by Morrison (1951). These particular stains have stained the majority of the radula (many stains do not . . . and sometimes these do not), leaving unstained the tips of denticles of the older, enamelized teeth or the entire older tooth. The bases of the older teeth are often stained when the entire tooth will not pick up the stain. The desired stain may be added, in very small quantities, directly to the clear CMC. CMC may be purchased pretinted with acid fuchsin, but one may wish to alter (probably increase) the concentration. Addition of enough acid fuchsin to attain a translucent, cherry color in the mounting medium is desirable. These acid stains, together with an extremely slight addition of a basic stain (especially methylene blue) to the CMC will usually stain the entire radula quite well, including older teeth and denticle tips. This combination of stains (fairly heavy on the acid stain and very light on the basic stain) maintains the one-step stain/mounting technique, as well as producing an entirely stained radula.

The combination of stains mentioned above produces a radula of generally one color. For cases in which the radula is large enough to be handled with confidence, a dip in an appropriate acid stain dissolved in water, a water rinse, followed by a dip in an appropriate basic stain dissolved in water can produce a radula with the younger, chitinous teeth (and possibly older teeth and/or the bases of them) stained one color, while the older enamelized teeth are stained a second color (see Meeuse, 1950:29). From this point, the radula is given a final rinse in water and can immediately be mounted using the clear CMC. The effect of concentration and type of stain varies with the type of radula, and requires some experimentation to achieve the desired effect.

Advantages

Becuase a small radula can be placed directly from NaOH to the CMC stain/mounting medium, the method has the advantage of a single handling of minute radulae. This feature is essential with extremely minute radulae which are easily lost due to excessive handling. With acid fuchsin stain in the mounting medium, the radula is simultaneously stained and mounted; therefore, use of water soluble CMC eliminates rinsing the radula and carrying it through several solutions of an alcohol or alcohol/xylene series.

Since some clearing action is provided by the CMC, the radula need not be completely clean of tissue in routine preparations.

Disadvantages

Due to the simple, quick-staining technique, the radula cannot be stained and destained to obtain the perfect density of staining. It also cannot undergo multiple stainings. However, this type of treatment is usually given to large radulae and generally cannot be accomplished with minute ones.

The use of CMC for large radulae has been found to be undesirable because of the large distance required between the cover slip and the slide. Initially, such a mount seems normal, but with time large bubbles form under the cover slip. The ring of sealant around the cover slip usually separates, allowing moisture from the CMC to evaporate, which in turn allows the CMC to contract, pulling air bubbles in from the margins of the mount. Medium-sized, easily handled radulae may be mounted with CMC, but because of their size they may retain too much fluid to be placed directly into the mountant following removal from NaOH; a water wash may be required between these two steps.

Acknowledgments

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SEDIMENT PREFERENCE OF THE FRESHWATER ASIATIC CLAM, *CORBICULA FLUMINEA*

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ABSTRACT

Corbicula fluminea, *the Asiatic clam, occurs in well-oxygenated lotic systems in sediments of various compositions. This study reports on rigorously controlled studies of* Corbicula *preferences of fine sand (predominantly between 0.25–0.7 mm particle size), organically enriched fine sand (predominantly between 0.25–0.7 mm particle size), coarse sand (predominantly 2.5–4.5 mm particle size), and no substrate in artificial streams in laboratory and field-laboratory settings using a paired choice design. In both the laboratory and field-laboratory,* Corbicula *preferred the sediments in the decreasing order of fine sand - organically enriched fine sand - coarse sand - no substrate. The density of* Corbicula *at an industrially uninfluenced site in the New River was significantly greater in fine sand (452 clams/m² with 70% of the sediment in the 0.35–0.60 mm particle size range) than coarse sand/gravel (177 clams/m² with 90% of the sediment in the 4.5–38.0 mm particle size range). The invasion of* Corbicula *into new habitats has been facilitated by the ability of the clam to utilize a wide variety of substrates, from fine sand to gravel. This study suggests that rivers with fine, well-oxygenated sand substrates would be optimal for establishment of* Corbicula *populations in newly colonized sites.*

Corbicula fluminea, the introduced Asiatic clam, is a species that flourishes in well-oxygenated lotic systems. In these habitats, *C. fluminea* inhabits nearly all sediment types to varying degrees (Horne and McIntosh, 1979; Rodgers *et al.*, 1979). Elimination or reduction of *Corbicula* populations has been recorded in association with sediments of high organic and low oxygen content (Aldridge and McMahon, 1978; McMahon, 1979; Eng, 1979). Respiration was shown by Dudgeon (1980) to be correlated inversely with mean particle size and perhaps related to increased metabolic demands of clams in fine substrates.

Densities of *Corbicula* in North America are greatest in well-aerated sand or sand-gravel mixtures (McMahon, 1983). *Corbicula* became established in the New River in southwestern Virginia around 1977 (Rodgers *et al.*, 1977). Graney *et al.* (1980) determined that *Corbicula* showed little discernible substrate preference within and outside a thermal discharge at the Glen Lyn Power Plant, Virginia, achieving maximal densities of 11,522 clams/m² in the discharge (sand to sand-gravel) and 2,286/m² in uninfluenced regions of the river at the plant in fine sand to sand sediments. Upstream of the Glen Lyn Plant, establishment of *Corbicula* has required more time (e.g., ~3 years). Cherry *et al.* (in press) have documented clam densities of 3,397–23,689/m² at an industrial pumphouse station (Celanese Fibers Corporation, Narrows, Virginia) 9.9 km upstream of the Glen Lyn Plant. This site is thermally uninfluenced and is characterized by well-oxygenated sediment with 68% of the particles in the size range of 0.25–0.7 mm.

Thus far, conventional wisdom of *Corbicula* distributional ecology has been that clams prefer coarse sand (1.5–2.5 mm) or mixed sand/gravel (2.5–60 mm) based upon field sampling results. A combination of rigorously controlled preference studies in the laboratory, field-laboratory, or in field validation experiments

has not been attempted. Objectives of the research herein were to determine the preference of adult *Corbicula* for distinct sediment size classes (0.2–40 mm) using a paired choice experimental design. Preference trials were performed in a formal laboratory artificial stream and field-laboratory setting and subsequently validated by field sampling in the New River.

Materials and Methods

Laboratory Preference Study

Preference trials were conducted in February, March, and April 1984 at the University Center for Environmental Studies Ecosystem Simulation Laboratory (ESL) at Virginia Polytechnic Institute and State University (Va Tech). Sediment preference chambers were constructed using plexiglass (17.5×17.5×1.5 cm). Three chambers were placed in each of six artificial streams (Fig. 1; Farris *et al.*, in review). The circular artificial streams have a 20-l capacity and are circulated by a gear-driven paddle wheel system to provide a uniform current flow similar to the river environment. Each stream received dechlorinated Blacksburg town tap water (water quality summarized in Table 1) at a flow rate of 300–400 ml/min which resulted in 21.6–27.0 turnovers per day. Water temperatures ranged from 10 to 17°C. Adult Asiatic clams (12–17 mm shell length) were obtained from the New River and acclimated to laboratory conditions for 5–7 days. Fine sand (72% between 0.25–0.7 mm), organically enriched fine sand (72% between 0.25–0.7 mm), and coarse sand (83% between 2.5–9.0 mm) sediment types were chosen for testing in these experiments based on their suspected relevance to *Corbicula* in the New River (Graney *et al.*, 1980). Fine sand was obtained in the New River near the Celanese Fibers Corporation and was sterilized prior to use by drying at 90°C for 24 hr and 500°C for 24 hr. Organically enriched fine sand was prepared by freeze drying *Elodea* sp. and *Nasturtium* sp. (water cress) in liquid nitrogen, crushing the frozen material, and mixing the organic matter 50:50 by volume (15:85 by weight) with sterilized fine sand. Coarse sand was obtained from a small fast flowing stream (Sinking Creek) near the Va Tech campus. Gravel was obtained from an aquarium supplier in Blacksburg. No substrate consisted of stacked 0.635 cm plexiglass plates.

For each preference trial, two substrates were placed side-by-side with a sharp, linear demarcation between them in each preference chamber (Fig. 1). Five adult clams were placed umbo down along the line of demarcation. Three replicates were used for each pair of sediments compared during the experiment: no substrate vs fine sand, no substrate vs organically enriched fine sand (hereafter referred to as "organic" in tables), no substrate vs coarse sand, fine sand vs organically enriched fine sand, fine sand vs coarse sand, and organically enriched fine sand vs coarse sand. Positions of the five *Corbicula* were traced for 7 days after preliminary preference trials of 3 weeks suggested this interval

TABLE 1. Water quality parameters for the laboratory experiments (ESL), field-laboratory experiments (Glen Lyn), and field survey. The range is below the mean for each parameter in parentheses. Sample sizes are n=2 for the ESL streams, river-fed streams at Glen Lyn, and for the field survey.

	Site		
Parameter	ESL (Laboratory)	Field-Laboratory	McCoy, Virginia
pH	7.75 (7.7-7.8)	8.25 (7.8-8.7)	8.7 (8.6-8.8)
Temp (°C)	14.0 (10-17)	13.0 (11-20)	18.5 (15-22)
Water Hardness (mg/l as $CaCO_3$)	57.5 (55-60)	95 (90-100)	90 (90)
Alkalinity (mg/l as $CaCO_3$)	27.0 (26.0-28.0)	57.5 (55-60)	53.5 (50-57)

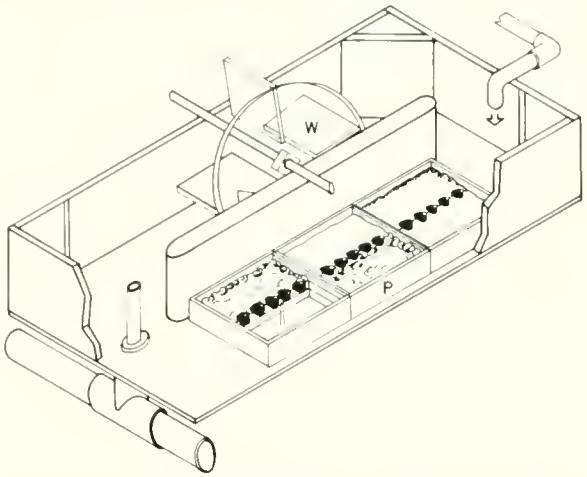

FIG. 1. Artificial stream system and plexiglass sediment preference chambers (P) used in laboratory substrate preference experiments at the Ecosystem Simulation Laboratory. Inflow water (arrow) is circulated by a paddle wheel (W) attached to a single speed gear motor.

was more than sufficient for clams to attain a final, permanent position in the preference chamber.

Field-Laboratory Preference Study

Sediment preference experiments were conducted in June, August, and October 1984 at a field-laboratory located at the Glen Lyn Power Plant adjacent to the New River. New River water was delivered from submerged pumps to 4.6-m fish hatchery troughs at the rate of 4 l/min (see Clark *et al.*, 1980). The depth of the water was maintained at 12–14 cm, resulting in 19.8–23.0 turnovers per day. Water temperatures ranged from 11 to 20°C. Plexiglass sediment preference chambers described earlier were placed on top of 8-cm platforms to minimize the potential of river silt settling onto the chambers. The experimental protocol used in the field-laboratory study was identical to the formal ESL study except all chambers and sediment preference trials were placed in one stream. The clams used for these studies were collected from the Celanese Fibers Corporation pumphouse in April and May 1984 and maintained in a hatchery trough at the Glen Lyn Plant. New River water quality for these experiments is summarized in Table 1.

Field Sampling

Estimates of the density of *Corbicula* were made on September 9 and December 18, 1984, in the New River at McCoy, Virginia. This site was chosen because: (1) it receives no industrial influence and, therefore, represents a natural *Corbicula* population in the New River, (2) the sampling region has several distinct substrate types relative to particle size in close proximity under nearly equal current regimes, and (3) accessibility for sampling a 0.3-m water depth was advantageous for sampling gear. Density estimates were derived for two substrate types, fine sand and sand/gravel, by removing triplicate samples from each area with a Surber sampler (0.1 m^2 sampling area). Each sediment-clam sample was placed individually in buckets and returned to the laboratory for analysis. Clams were handpicked from each sample. Sediment was dried and sieved to determine sediment composition by weight using a Metler PC-440 electronic balance (accuracy, ±0.0005 g). Adult (>8.0 mm shell length) and juvenile (~2.5–8.0 mm shell length) clams were measured for shell length by vernier calipers (accuracy, ±0.05 mm). Estimates of "larval" (veliger) density in each sample were made by analyzing the sediment fractions that were <2.5 mm from each replicate.

Statistical Treatment of Data

Preference experiments were analyzed by one-way analysis of variance (ANOVA) (Steel and Torrie, 1960) at each observation period and for each sediment pairing. For each pair of sediments, three possible outcomes were compared: (1) clams would reside in sediment A, (2) clams would reside in sediment B, or (3) clams would remain in the region of the demarcation between sediment A and sediment B. If a significant difference existed by the ANOVA F-test ($\alpha = 0.05$), Duncan's Multiple Range Test was performed to determine which group(s) were significantly different (Steel and Torrie, 1960). Results of *Corbicula* densities observed in the field in coarse and fine sediments were analyzed by the student's t-test.

Results

Laboratory Preference Study

Corbicula were found to prefer any substrate (fine sand, organically enriched fine sand, or coarse sand) over no substrate at all (Table 2). Clams were observed to move rapidly into sediments. After 1 hr, 70–80% of the clams were buried in the sediments offered. By the third

TABLE 2. Analyses of variance for *Corbicula* sediment preference of fine sand versus no substrate, organically enriched fine sand versus no substrate, and coarse sand versus no substrate conducted at the Ecosystem Simulation Laboratory and Glen Lyn field laboratory. Means with the same letter are not significantly different ($\alpha = 0.05$) using Duncan's Multiple Range Test.

		% Residence at Time				
Site	Substrate	1 hr	F-ratio (p-value)	Day 1	F-ratio (p-value)	Days 3-7[1]
ESL	Fine	71.1±31.8[a]		97.8±6.7[a]		100.0±0
	No Substrate	4.4±8.8		0±0[b]		0±0
	Uncommitted[2]	25.5±21.8		2.2±6.7[a]		0±0
	Organic	82.2±27.3[a]		97.8±6.7[a]		100.0±0
	No Substrate	4.4±8.8[b]		0±0[b]		0±0
	Uncommitted	13.4±27.9[b]		2.2±6.7[b]		0±0
	Coarse	82.2±27.0[a]		97.8±6.7[a]		100.0±0
	No Substrate	8.9±20.2[b]		2.2±6.7[b]		0±0
	Uncommitted	8.9±14.5[b]		0±0[b]		0±0
Glen Lyn	Fine	46.7±46.9[a]		100.0±0		100.0±0
	No Substrate	2.2±6.2[b]		0±0		0±0
	Uncommitted	51.2±46.9[a]		0±0		0±0
	Organic	62.2±27.2[a]		100.0±0		100.0±0
	No Substrate	2.2±6.7[b]		0±0		0±0
	Uncommitted	35.1±30.0[a]		0±0		0±0
	Coarse	46.7±24.5[a]		82.2±27.2[a]		100.0±0
	No Substrate	6.7±10.0[b]		4.4±8.8[b]		0±0
	Uncommitted	46.6±21.9[a]		13.4±12.7[b]		0±0

[1]All clams resided in the substrate from Day 3 to Day 7. Analyses of variance are not quoted since the data are unsuitable for this statistical method.
[2]Uncommitted clams were designated as those that did not move from the line of demarcation between sediments.

day, 100% of the clams were buried in all sediments, and none remained exposed (Table 2).

Clams consistently preferred fine sand or organically enriched fine sand when coarse sand was the alternative choice (Table 3). The choice of fine sands was significant by Day 3 (Table 3), although, for fine sand alone, the choice was made sooner (on Day 1; Table 3).

When clams were offered the choice of organically enriched fine sand vs fine sand, the preference pattern was less distinct than for either of these sediments vs no substrate or coarse sand (Table 3). Ultimately, fine sand was significantly preferred over organically enriched fine sand (Days 6 and 7; Table 3).

Field-Laboratory Preference Study

Results of these preference trials were similar to experiments conducted at the ESL. Any substrate (e.g., fine sand, organically enriched fine sand, and coarse sand) was significantly preferred over no substrate at all (Table 4). By Day 3, all clams were buried in fine sand, organically enriched fine sand, and coarse sand when no substrate was the alternative (Table 4).

Clams did not prefer coarse sand when offered fine or organically enriched fine sand; however, fine sand was significantly preferred sooner (Day 1; Table 4) than organically enriched fine sand (Day 3; Table 4). By Day 7, 78% of the clams resided in fine sand when coarse sand was the alternative, and 71% resided in organically enriched fine sand when coarse sand was the alternative (Table 4). Preference trials of fine vs organically enriched fine sand showed clams preferred fine sand. By Day 5, 60% of the clams resided in fine sand substrate (Table 4).

Field Sampling

The density of *Corbicula* was two to three times greater in fine sand (75% of the sediment was in the 0.35–0.60 mm size range) than coarse

TABLE 3. Analyses of variance and percent residence for *Corbicula* sediment preference experiments at the Ecosystem Simulation Laboratory. Means with the same letter are not significantly different ($\alpha = 0.05$) using Duncan's Multiple Range Test.

	% Residence at Time				
Substrate	1 hr	Day 1	Day 3	Day 5	Day 7
Organic[1]	40.0±30.0	51.1±38.8^{a}	64.4±23.4^{a}	66.7±20.7^{a}	76.7±15.1^{a}
Coarse	26.7±30.0	28.9±24.5^{a,b}	21.1±17.8^{b}	30.0±20.9^{b}	20.0±17.9^{b}
Uncommitted	33.3±30.0	20.0±21.1^{b}	14.4±16.3^{b}	3.3±8.2^{c}	3.3±8.2^{c}
Fine[2]	32.2±27.9	62.2±6.7^{a}	63.3±36.7^{a}	70.0±16.7^{a}	70.0±27.6^{a}
Coarse	27.8±20.0	24.4±16.7^{b}	6.7±10.3^{b}	13.3±16.3^{b}	23.3±29.4^{b}
Uncommitted	47.8±24.5	13.3±17.3^{b}	30.3±30.3^{a,b}	16.7±8.1^{b}	6.7±16.3^{b}
Fine[3]	24.4±26.0	64.1±27.3^{a}	37.0±27.3	70.0±35.2^{a}	73.3±30.1^{a}
Organic	47.7±20.0	31.9±14.5^{b}	37.0±27.3	13.3±16.3^{b}	23.3±26.6^{b}
Uncommitted	28.9±28.4	14.1±14.1^{c}	25.9±23.3	16.7±19.7^{b}	3.3±8.2^{b}

[1] F (and in parentheses, p-values) were 0.44 (0.6464); 2.71 (0.0866); 11.71 (0.0009); 19.50 (0.001); 43.37 (0.0001) for time 1 hr through Day 7.

[2] F (and in parentheses, p-values) were 1.67 (0.2085); 28.50 (0.0001); 6.15 (0.0112); 29.67 (0.0001); 10.25 (0.0016) for time 1 hr through Day 7.

[3] F (and in parentheses, p-values) were 1.98 (0.1605); 11.90 (0.0030); 0.48 (0.6245); 9.61 (0.0021); 13.93 (0.0004) for time 1 hr through Day 7.

TABLE 4. Analyses of variance and percent residence for *Corbicula* sediment preference experiments at Glen Lyn. Means with the same letter are not significantly different ($\alpha = 0.05$) using Duncan's Multiple Range Test.

	% Residence at Time				
Substrate	1 hr	Day 1	Day 3	Day 5	Day 7
Organic[1]	35.6±27.9^{a,b}	44.4±29.6^{a}	53.3±30.0^{a}	60.0±22.4^{a}	71.1±17.6^{a}
Coarse	15.6±26.0^{b}	40.0±33.1^{a,b}	37.8±27.2^{a}	40.0±22.4^{b}	15.6±13.3^{b}
Uncommitted	48.9±30.2^{a}	15.6±19.4^{b}	8.9±20.2^{b}	0±0	4.4±8.8^{b}
Fine[2]	26.7±17.3^{b}	60.7±20.0^{a}	71.1±20.3^{a}	69.6±28.5^{a}	77.8±27.3^{a}
Coarse	8.9±10.5^{c}	24.4±19.4^{b}	24.4±21.9^{b}	22.9±21.1^{b}	22.2±27.3^{b}
Uncommitted	64.4±13.3^{a}	8.9±14.5^{b}	4.4±8.8^{c}	7.4±14.1^{b}	0.0^{c}
Fine[3]	20.0±34.6^{a}	40.0±17.3	46.7±24.5^{a}	60.0±14.1^{a}	62.2±23.3^{a}
Organic	17.8±23.3^{a}	40.0±24.5	44.4±24.0^{a}	37.8±15.6^{b}	33.3±22.4^{b}
Uncommitted	62.2±39.3^{b}	20.0±22.4	13.3±22.4^{b}	2.2±6.7^{c}	4.4±13.3^{c}

[1] F (and in parentheses, p-values) were 3.24 (0.050); 2.78 (0.0825); 6.68 (0.0049); 25.20 (0.0001); 60.78 (0.0001) for time 1 hr through Day 7.

[2] F (and in parentheses, p-values) were 36.91 (0.0001); 24.4 (0.0001); 32.69 (0.0001); 19.45 (0.0001); 29.10 (0.0001) for time 1 hr through Day 7.

[3] F (and in parentheses, p-values) were 5.15 (0.0138); 2.57 (0.0973); 5.59 (0.0102); 46.91 (0.0001); 18.44 (0.0001) for time 1 hr through Day 7.

sand/gravel substrate (90% of the sediment was in the 4.50–36.00 mm size range) in the New River. Sediment composition of the December 18 samples is summarized in Figure 2. The densities of adult and juvenile *Corbicula* were approximately the same for both samples in the respective sediments (Table 5). After combining the results of both September 9 and December 18 samples, a t-test indicated that the densities of the clams were significantly greater in the finer sand substrate than in coarse sand/gravel. These results are consistent and supportive of the laboratory and field-laboratory preference experiments.

Discussion

Sediment preferences of *Corbicula* were consistent in both laboratory and field-laboratory experiments. Although some temporal differences existed for some comparisons, relative to where the experiment was performed (e.g., fine sand vs coarse sand, and fine sand vs organically enriched sand), the preferences were ultimately identical (i.e., fine sand was preferred

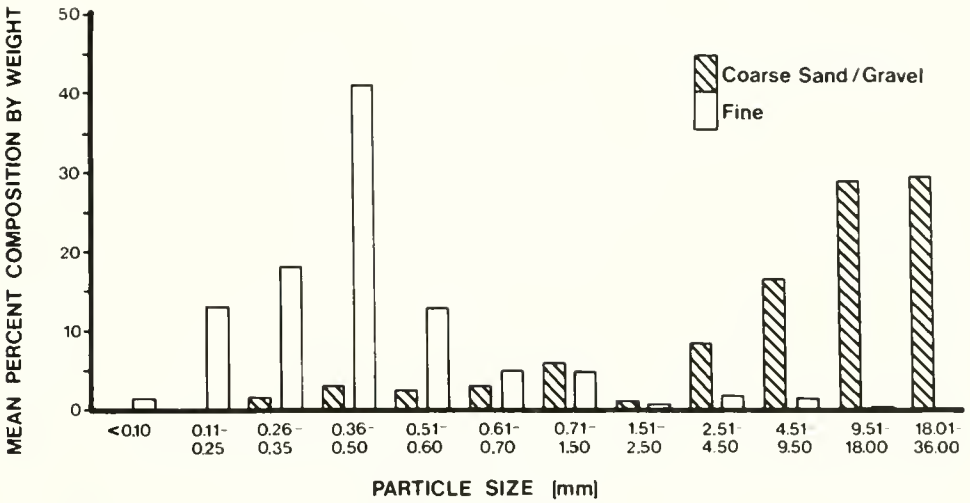

FIG. 2. Mean percent composition by weight of coarse sand/gravel samples and fine sand samples from the New River taken by Surber sampling for *Corbicula* densities.

TABLE 5. Densities of larval (≤1 mm), juvenile (1.0 to 8.0 mm) and adult *Corbicula* (>8.0 mm) within the New River at McCoy, Virginia.

Collection Date	Sediment Type	n	Larval Density (individuals/m²)	t-test (p-value)	Juvenile/Adult Density (individuals/m²)	t-test (p-value)	Shell length (Means±SD)	n	t-test (p-value)
9 Sept 1984	Fine sand	3	--	--	398.1 ± 376.6		10.28 ± 2.34	123	
	Coarse Sand/ gravel	3	--	--	139.8 ± 59.9	1.173 (0.3580)	10.52 ± 3.83	39	0.4091 (0.6831)
18 Dec 1984	Fine sand	3	14.3 ± 6.51	--	505.72 ± 67.2		11.08 ± 3.16	141	
	Coarse sand/ gravel	3	14.37 ± 16.38	--	215.2 ± 32.3	6.750 (0.0084)	11.69 ± 2.46	50	1.3237 (0.1871)
Combined	Fine sand	6	--	--	451.9 ± 24.90		10.71 ± 2.83	264	
	Coarse sand/ gravel	6	--	--	177.5 ± 59.6	2.625 (0.0425)	11.35 ± 2.96	89	1.799 (0.0729)

for the aforementioned comparisons). Thus, it was possible to rank the observed experimentally identified preferences to predict the sites/substrates of varying densities of clams located in the field. The preferences observed in these studies were in the following descending order: fine sand - organically enriched fine sand - coarse sand - no substrate. The field sampling, which found clams to be significantly denser in the fine sand than coarse sand/gravel under similar environmental conditions of current, temperature, light, and season, corroborated our predictions in this study.

The importance of sediment to population dynamics and success of *Corbicula* invasion has been previously emphasized by several investigators. Eng (1979) discussed the use of incrustaceans along the Delta-Mendota concrete canal by *Corbicula* as a nursery zone and refuge for larvae and small juveniles. Sickel and Burbank (1974) investigated preferences of newly released juveniles for substrates and found coarse sand was preferred over mud (potentially oxygen-limiting) or bare concrete (ecologically barren surface). McMahon (1983) suggested that flourishing *Corbicula* populations in streams that are canalized may optimize the environment for this species by eliminating the reducing environments of mud and silt under fast flowing conditions. The importance of thermal inputs from power plants and other industrial installations has been documented previously by several investigators (Rodgers *et al.*, 1977; McMahon, 1977; Scott-Wasilk *et al.*, 1983). Graney *et al.* (1980) surveyed *Corbicula* populations at the Glen Lyn Power Plant in thermally influenced and uninfluenced stations with various substrate compositions and concluded that thermal discharges had a greater influence upon clam survivorship and density than substrate composition. It is important to note that thermal effluents allow clams to sustain reproducing populations over the winter where they would otherwise not occur (Graney *et al.*, 1980; Scott-Wasilk *et al.*, 1983; McMahon, 1982).

Corbicula has continued to invade new habitats in North America and is now found in nearly every state in the continental United States (McMahon, 1982). The ability of *Corbicula* to utilize a wide variety of substrates, from fine sand to gravel (which *Corbicula* finds inhabitable), has enhanced its success. However, this study suggests that rivers with fine, well oxygenated sand substrates would be optimal for establishment of *Corbicula* populations in newly colonized sites.

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A WEST INDIAN COLUMBELLID NEW TO THE GENUS *STEIRONEPION*

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ABSTRACT

In 1850 C. B. Adams described Pleurotoma maculata *from Jamaica. Subsequent beach specimens from Varadero Beach, Cuba, and the Bahamas, as well as examples from dredged sand at Marianao, Havana, Cuba (described as* Turrijaumelia jaumei *Sarasúa, 1975), further extend the known range. A morphological assessment would suggest that the species be placed in the columbellid genus* Steironepion, *thus adding a third species to that genus from the Caribbean marine basin, and making* Turrijaumelia *a subjective synonym of* Steironepion.

In "Poeyana", published under the auspices of the Institute of Zoology, Cuban Academy of Sciences, Havana, Cuba, Dr. Hortensia Sarasúa described a new turrid gastropod, erecting the new genus and species *Turrijaumelia jaumei.* Although the type specimen of *Pleurotoma maculata* Adams, 1850, figured by Clench and Turner, is a worn specimen, there seems little doubt that *T. jaumei* should be synonomized with that taxon. None of the Cuban or Bahamaian specimens were live-taken.

Perusal of George Radwin's comprehensive treatment of the family *Columbellidae* in the western Atlantic, would suggest adding this species to the genus *Steironepion* which now contains the Caribbean species *S. minor* (C. B. Adams, 1845) and *S. moniliferum* Sowerby, 1844). Placement of this columbellid in the *Turridae* by Adams and Sarasúa may have resulted in their considering the rather swollen anal sinus as a turrid notch.

Since C. B. Adams' description of this species is very brief, it is deemed desirable to translate and reproduce below Dr. Sarasúa's detailed description of this very attractive little shell.

Turrijaumelia, new genus

Description: Shells small, slender, not fragile but delicate. Large nuclear whorls, smooth and bulbous, the post nuclear whorls are characterized by angular perimeters and well defined sutures. Sculpture reticulated, formed by thin axial ribs, crossed by smooth spiral cords, forming sharp rib projections on the lower half of the whorls. The spaces between the reticulated sculpture reveal numerous microscopic axial threads. Aperture narrow, sigmoidal, with the anal channel somewhat enlarged. Outer lip with slight stromboid notch, showing interior liration and the anterior canal recurved backwards and to the right.

Genotype—*Turrijaumelia jaumei,* new species

Discussion: Among the many genera of the *Turridae,* we have not been able to find one fitting our lot; the bulbous and smooth nuclear whorls, the angular periphery of the post nuclear whorls, the smooth spiral cords, the rib projections and the peculiar microscopic axial threads in the reticulated spaces, give us what

we believe to be sufficient characteristics to establish the new genus *Turrijaumelia.*

Turrijaumelia jaumei, new species

Description: Shell small, elongated and graceful, of delicate and vitrious appearance; nuclear whorls two, large bulbous and smooth, followed by 4-4.25 post-nuclear whorls, well defined suture and angular periphery. The last whorl narrows and forms the siphon canal completing the graceful appearance of the species. Sculpture consisting of marked narrow ribs, more or less 12 on the last whorl, higher on the lower half of the whorls and more slender at the base of the shell, crossed by smooth spiral cords, well separated. At the top half of the whorls, which are strongly sloped, there are 3 or 4 spiral cords of the same width, separated by a space more or less the same width as the width of these cords. The spiral cords on the lower half of the whorls are wider and more separated from one another, the first extends from the middle line of each whorl, and these in turn form the sharp rib projections which point upwards; three of these spiral cords are observed on the last whorl. At the base of the last whorl are two spiral cords, the first of which may have slender projections, on the second these may appear instead as small nodules. On the siphon canal are two spiral cords of small nodules, followed by three narrow cordlets.

In the translucent spaces of the reticulated area, which on the lower half of the whorls, are large and rectangular, are microscopic axial threads, straight and parallel, separated from one another by spaces more or less the same as their width; these axial threads reach the sides and surface of the ribs, and at the point appear slightly curved. On the siphon canal the spiral sculpture is crossed by microscopic axial lines. The outer lip of the aperture reveals four denticulations on the inside border formed by the termination of the lirations, the two upper ones being clearly visible. The general color of the shell is white, a few brown spots are observed on the upper part of the spiral cords where the whorls slope downward; the base of the last whorl may be yellowish, and a touch of brown may appear on the last rib. On the nuclear whorls, at the beginning of the suture, there is generally a brownish spot.

The measurements given for the width of the shells, are without consideration to the sculptural projections.

	Length	Width (greatest)	Width (narrowest)	
Holotype	4 mm	1.75 mm	1.70 mm	Marianao, Habana
Paratype	4 mm	1.60 mm	1.50 mm	Marianao, Habana
Paratype	4.1 mm	1.50 mm	1.40 mm	Marianao, Habana

The type shells form part of a lot of 19 specimens, dredged from sand at a depth of approximately 20 metres, were taken offshore at Marianao, Habana, and collected by Sr. Primitivo Borro. Another three specimens were found by the author in sand from the same location. Type catalog No. 36 (holotype) and 37 and 38 (paratypes.)

Steironepion maculatum (C. B. Adams, 1850)

(Figs. 1, 2)

Synonomy–

1850 *Pleurotoma maculata* C. B. Adams, 1850, *Contributions to Conchology,* No. 4, p. 62 (Jamaica); 1950 Clench and Turner, *Occasional Papers on Mollusks,* vol. 1, No. 15, p. 305, pl. 29, fig. 3 (holotype)

1887 *Pleurotoma (Drillia) maculata* Verkruzen, Paetel, *Catalog der Conchylien–Sammlung von Fr Paetel,* vol. 1, p. 56 (Jamaica). [listing only].

1975 *Turrijaumelia jaumei* Sarasúa, *Poeyana* (Havana), No. 140, pp. 12-15, (20 metres, off Marianao, Habana, Cuba).

Records–BAHAMAS: West Beach, Staniel Cay, Exhumas, Dieter Cosman collector, 1966. CUBA: Varadero Beach, North coast of Cuba (drift), C. John Finlay collector, 1952; Marianao, Habana, Primitivo Borro and Hortensia Sarasúa, from sand dredged in 20 metres. JAMAICA: C. B. Adams, 1850; Paetel, 1887.

Genus ***Steironepion*** Pilsbry and Lowe, 1932

Synonomy–

1932 *Steironepion* Pilsbry and Lowe, *Proc. Acad. Nat. Sci. Philadelphia,* vol. 84, p. 57 (type by original designation: *Mangelia melanosticta* Pilsbry and Lowe, 1932).

1943 *Psarostola* Rehder, *Proc. U. S. Nat. Mus.,* vol. 93, No. 3161, p. 198 (type by original designation: *Columbella monilifera* Sowerby, 1844).

1975 *Turrijaumelia* Sarasúa, *Poeyana* (Havana), No. 140, pp. 12-15, (type by monotypy: *T. jaumei* Sarasúa, 1975)

This interesting group of small columbellids with a reticulated or beaded sculpture and a strong anal notch has been placed in the turrids by many authors until Rehder (1943), Keen (1971) and Radwin (1977) showed its columbellid affinities both in shell and radular characters. Curiously, Sowerby (1844), Duclos (1848 and

FIGS. 1, 2. *Steironepion maculatum* (C. B. Adams, 1850). Beach drift, Varadero Beach, north coast of Cuba, 1952, 4.5 mm, C. J. Finlay collector.

Tryon (1883) also placed *Steironepion moniliferum* (Sowerby, 1844) in the Columbellidae. Radwin (1977) removed *Steironepion* from the genus *Nassarina* and considered it a full genus, a view in which I concur.

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ACTIVITY PATTERNS AND HOMING IN TWO INTERTIDAL LIMPETS, JORDAN GULF OF AQABA

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ABSTRACT

The foraging and homing behavior of Cellana radiata *(Born) and* Siphonaria laciniosa *(Linné) occurring in the rocky intertidal zone has been determined.* C. radiata, *a prosobranch, forages when submerged during day and night, is a temporary homer and migrates up and down with changes in sea level.* S. laciniosa, *a pulmonate, forages when submerged but only after sunset and is a rigid homer. Homing behavior in relation to desiccation and density dispersion are discussed. Migration, intra- and interspecific competition are also discussed.*

Activity patterns, including foraging and homing of many prosobranch and pulmonate limpets, have been investigated for many years. The patterns, especially foraging or feeding excursions, have been found to be quite variable as to when and under what conditions they occur. Homing has also been found to be variable and various reasons have been proposed for such

behavior including reduction of desiccation, better utilization of resources, especially food and protection from predators (Underwood, 1979; Branch, 1981; Garrity and Levings, 1983 and included references).

There are only two limpets found in the rocky intertidal zone along the coast of Jordan, the patellid *Cellana radiata* (Born, 1778) (alias *C. rota* (Gmelin, 1791)) and the pulmonate *Siphonaria laciniosa* Linné, 1758 (alias *S. kurracheensis* Reeve, 1856). *C. radiata* is the larger of the two species, reaching lengths of up to 48 mm, whereas *S. laciniosa* rarely exceeds 20 mm. Both species occur in the midlittoral zone of Stephenson and Stephenson (1949) within which Safriel and Lipkin (1964) designated a higher chthamalid zone and a lower *Tetraclita* zone. *C. radiata* has a wide vertical distribution, ranging from above the chthamalid zone to below the *Tetraclita* zone and occurs on vertical to horizontal surfaces of boulders, pebbles and various types of slab substrata. *S. laciniosa,* in contrast, is mostly restricted to near the chthamalid zone (within the range of *C. radiata*) and occurs more commonly on horizontal, soft, calcareous substrata rather than on hard substrata. Both limpets are grazers, feeding on microalgae.

Prior to the present report, nothing was known of the foraging and homing behavior of *Cellana radiata* and *Siphonaria laciniosa* in the Red Sea. Voucher specimens of both species are on deposit in the U.S. National Museum of Natural History and in the reference collection of the Marine Science Station in Aqaba, Jordan.

The Rocky Intertidal

The rocky intertidal zone along the coast of Jordan is quite variable, ranging from granitic boulders to multicolored pebble beaches to low profile slab or platform beaches. The latter may be sandstone, gravel-pebble conglomerate, beach rock or fossil coral reef consisting of eroded coral heads in a cemented calcareous matrix. Wave action on slab beaches is usually minimal as they are protected by outer reef crests or occur on the leeward side of land projections.

The mixed tides have a spring range of about 1 m and a neap range of around 50 cm (Fishelson, 1973; Hulings, unpublished data). The diurnal inequality averages 4.2 cm for the high tides, and 4.7 cm for the lows (Hulings, unpublished data). Fluctuations in sea level of up to 1 m occur. From December through May, the sea level is the highest; from July through September-October it is the lowest (Fishelson, 1973; Hulings, unpublished data). From late September through November there is a gradual rise in sea level, and from late May through June there is a gradual lowering.

There is no river discharge into the Gulf of Aqaba and this in combination with low rainfall (23 mm/yr, Morcos, 1970), high evaporation (up to 4 m/yr, Anati, 1976), prevailing N-NNE, hot and dry winds (Hulings, 1979) results in a constant salinity of 40.5 to 41.5 ppt (Paldor and Anati, 1979). The mean air temperature has a wide range, from about 16°C in January to 32°C in August (Jordan Meterological Department), while water temperature has a much narrower range, from 20°C in February to 27°C, in August-September (Morcos, 1970).

Methods and Materials

Most of the data on the activity and homing of *Cellana radiata* were obtained from specimens living on a low profile calcareous fossil reef platform in the midlittoral zone above the *Tetraclita* zone; additional data on *C. radiata* were obtained on specimens occurring on large and relatively smooth granitic pebbles. The shells and the home area were color-coded, using either enamel paint or fingernail polish. Three color-coded groups of 15 specimens, each occurring on the calcareous substratum and averaging 30.1 mm in length, were observed continuously from 6 October through 7 November 1983 and periodically through 15 February 1984. The 19 color-coded *C. radiata* occurring on the granitic pebbles averaged 24.0 mm in length and were observed from 6 October through 7 November 1983.

In order to obtain information on the overall movement of *Cellana radiata,* 55 individuals (average length of 25.4 mm) within a 1 m^2 area were painted and then observed from 11 September through 7 November 1983 on a daily basis and periodically through mid-June 1984. A 1 m^2 metal frame divided into 10×10 cm quadrates was put in the same place during low tide,

the time of observation, and removed after each observation.

For *Siphonaria laciniosa*, a total of 90 individuals, averaging 15.2 mm in length, were color-coded and observed from 10 September through 9 November 1983 and periodically through mid-July 1984. The 90 individuals consisted of four separate populations, two of which consisted of 12 and 34 individuals occurring on eroded coral reef heads having a very irregular surface; 25 specimens occurred on a relatively smooth, cemented, calcareous matrix, and a fourth population of 16 individuals occurred on beachrock of cemented granule-sized grains. Concurrent observations were conducted on six specimens averaging 13.2 mm in length kept submerged in an aquarium with running sea water.

Observations on *Cellana radiata* and *Siphonaria laciniosa* were made during day and night, spring and neap tides, flooding and ebbing tides and during complete submergence and emergence as well as combinations of the above.

Results

Cellana radiata became active soon after submergence and returned from foraging during the period from maximum flood tide to just before or after emergence. Movement during foraging was not continuous and the distance of the excursions varied from 3 to 35 cm. The direction of movement varied from predominately unidirectional to up to 45° from the main direction. Limited data indicates that the return is along the outgoing path. There were individuals that did not forage during consecutive cycles of submergence. During emergence, *C. radiata* remained inactive. The periods of foraging activity and inactivity occurred equally during day and night.

The homing behavior of *Cellana radiata* was extremely variable. Among three groups each of 15 color-coded specimens living on relatively flat calcareous substrata 38% were initially non-homers. For the homers, the percent of the individuals returning to the original home decreased to 4% over a period of 33 days. Similar decreases in homing were noted among other marked specimens on the large and smooth granitic pebbles. The decrease in the percent of homers was not, however, constant. Fluctuations in the percent occurred because of the return of some individuals to the original home after one or more days of absence. Many of those that left the original home subsequently established one or more new homes. In cases where the home was occupied by another individual, the homer returned to as close as possible to the home but did not dislodge the new occupant.

The average number of days that *Cellana radiata* occupied the original home was 11 and ranged from 1 to 22. Those specimens occupying a new home did so for an average of 3 days (range, 2 to 7).

The homing scar of *Cellana radiata* on a calcareous substratum was either entirely greenish in color or greenish with the periphery tan to white. The latter color pattern appeared to be characteristic of those individuals homing for extended periods. The color patterns disappeared, however, a few days after the home was vacated. No depressions, excavations or other physical markings in the scars were seen. Scars were absent on the hard granitic pebbles. On the soft calcareous substratum scars from *C. radiata* were as small as 11.0 mm in length.

The observations of the 55 marked *Cellana radiata* within the 1 m^2 area revealed that over a period of 55 days the number decreased from 55 to 6. The number leaving the area was offset, however, by immigrants entering the same area. The exodus was gradual as was the immigration into the area. The result was that the density in the m^2 area remained relatively constant, averaging 58 individuals/m^2 over a period of 55 days.

The direction of movement of 55% of the marked *Cellana radiata* from the area was toward the high water mark or vertical while 36% were to either side of the area and approximately parallel to the shoreline. The remaining 8% moved seaward or vertically downward. A similar pattern of upward and/or lateral movement was noted among non-homing individuals marked for homing observations. Homing continued among some individuals while migration occurred in others. There was no obvious directional movement of the immigrants into the m^2 area although there appeared to be net movement toward the high water mark. During May and June 1984, a general pattern of seaward

migration was noted among remnants of the originally marked populations.

The foraging activity of *Siphonaria laciniosa* was restricted when they were submerged and was begun only after sunset. Activity occurred either during flooding or ebbing tides but only as long as the individuals were submerged and usually within a minimum of 30 minutes after sunset, but more commonly 45 to 60 minutes after sunset. Excursions of up to 20 cm and averaging 54 minutes in length (range, 25 to 100 minutes) occurred. Movement was not continuous during the foraging excursions. The return to the home locality was usually along the outgoing path.

The number of *Siphonaria laciniosa* within a particular population foraging at a particular time was extremely variable. Rarely did all the individuals of a given population forage during one period of suitable conditions. In some cases, there was no foraging among any of the individuals of a given population on a particular occasion. There appeared, however, to be almost total foraging activity among all individuals within a population on successive periods of suitable conditions.

Without exception, all *Siphonaria laciniosa* homed following the foraging excursions, including specimens continually submerged in an aquarium. Furthermore, the homing was found to be rigid in that it was continuous over the period from 10 September through 9 November 1983. An exception was in three specimens which moved to a new home but subsequently remained at the new home. Observations through mid-July 1984 revealed all of the originally observed *S. laciniosa* occupying the same homes.

The scar of *Siphonaria laciniosa* occurring on calcareous substrata was white in the center and green on the periphery. The coloration disappeared, however, within a few days after the home was no longer occupied. The scar was usually a depression, part of which was commonly surrounded by a ridge. The surface of the depression tended to be smoother than the surrounding substratum. The depressions were generally more common among large than small specimens. Among both large and small individuals, the edge of the shell conformed to the configuration of the substratum.

Scars with the coloration pattern and depression were absent among *Siphonaria laciniosa* occurring on hard, non-calcareous substrata such as granular beach-rock and pebbles. Among these homing individuals, the edge of the shell conformed to the surface configuration of the substratum regardless of the irregularity.

Discussion

The patterns of foraging activity and homing in the two rocky intertidal limpets along the coast of Jordan are very different. The patellid, *Cellana radiata*, is a temporary or non-rigid homer, as well as being migratory. In addition, it is active both day and night but forages only when submerged. In contrast, the pulmonate, *Siphonaria laciniosa*, is a rigid homer and does not migrate; foraging occurs only after sunset and when it is submerged. The patterns of activity in both species occurred irrespective of tidal or lunar cycles.

Rao and Ganapati (1971) reported that *Cellana radiata* from the tropical west coast of India exhibited homing behavior but with no indication of whether homing was temporary or permanent. They further reported that homing occurred only on rough substrata and not on smooth surfaces and that movement occurred only during submergence. *Cellana radiata* from the Jordan Gulf of Aqaba has been found to home temporarily on smooth, as well as rough surfaces.

Cellana radiata from the Jordan Gulf of Aqaba exhibits the same temporary homing behavior as reported by Branch (1975) for *Patella granularis* Linné and by Mackay and Underwood (1977) for *C. tramoserica* (Sowerby). In addition, *C. radiata* generally fits the category of migratory species established by Branch (1981) for *Patella* spp. The homing behavior found in *Siphonaria laciniosa* is consistent with that of other siphonariids (Branch, 1981 and included references). The conditions and timing of foraging excursions in *S. laciniosa* are, however, different from that of other species summarized by Branch (1981) in occurring only when submerged and after sunset.

Homing behavior among intertidal limpets is often considered as a response to minimizing desiccation. In the case of the homing behavior

of *Cellana radiata* reported here, homing is considered insignificant in relation to desiccation. *C. radiata* is a temporary homer with a temporary scar and the edge of the shell usually does not fit closely to the substratum. In addition, during emersion the shell is raised from the substratum rather than being clamped down, the mantle cavity contains copius fluid and there is no formation of a mucus sheet reported by Wolcott (1973).

In the case of *Siphonaria laciniosa*, however, homing is considered significant in reducing desiccation. *S. laciniosa*, a rigid homer, returns to a permanent scar following foraging and there is a good fit of the edge of the shell to the substratum on soft (calcareous) and hard bottoms. And during emersion, the shell is clamped to the substratum.

The significance of homing in *Cellana radiata* may be related to what Mackay and Underwood (1977, p. 215) proposed for *Cellana tramoserica* which, as noted above, are similar in homing behavior. They hypothesized "homing behavior as an adaptation which regulates local density and dispersion to maximize utilization of food resources and, thus, to reduce intraspecific competition for food at high densities of limpets". Support for this hypothesis in *C. radiata* may be found in the results of the movement through a 1 m^2 area over a period of 58 days. During that period there was gradual emigration of marked individuals from the area and gradual immigration of new individuals into the area. The result of the emigration and immigration was that the density of individuals within the unit area remained relatively constant.

The pattern of shoreward or upward migration in *Cellana radiata* during late September through November is considered as a response to the increase in sea level, increased food supply and reduced physical extremes. As noted above, late September through November is the period of transition from lowest sea level (July through mid-September) to highest sea level (December through May). With an increase in sea level, more area is submerged for a longer period of time thus favoring increased food supply in the form of microalgae and a reduction in physical extremes. Thus, *C. radiata*, microalgal grazer and feeding only when submerged, takes advantage of the increased area of suitable conditions. The observed seaward or downward movement of *C. radiata* that occurred beginning in late May more or less coincided with a gradual lowering of the sea level. It is considered as an attempt to avoid the greater extremes in the physical environment and reduced food supply. A similar pattern of migration described above with, however, varying degrees, has been found among some prosobranch gastropods occurring in the rocky intertidal on the Jordanian coast (Hulings, unpublished data).

Siphonaria laciniosa responds in different ways to the change in sea level. As a nonmigrant, it remains in the same position regardless of the change in sea level. During the period of high sea level, it is submerged more often and for a longer period of time. It is during this period that *S. laciniosa* deposits egg ribbons during the night on exposed surfaces and that the hatching of veligers occurs (Hulings, in preparation). During the period of lowered sea level, air temperatures are higher and periods of emergence are longer. Thus, homing behavior as a response to lowered sea level minimizes desiccation.

Although an investigation of predation was not conducted, observations indicate a high mortality rate in *Cellana radiata* compared to *Siphonaria laciniosa* based on the finding of empty shells on the beach. A mortality rate of 22% was found among marked *S. laciniosa* over a 10-month period (no comparable data for *C. radiata*). What portion of the mortality is attributable to predation is not known. Most of the empty shells of both limpets did not exhibit physical damage.

The spatial distribution of *Siphonaria laciniosa* tends to be more clumped than widely dispersed. Pairs and groups of individuals occurring in close proximity to each other are fairly common. Recruitment into areas of established populations was noted, and in some cases, the recruits were close to older individuals. Thus, there appears to be no aggressive behavior nor territorial defense by *S. laciniosa*. A similar situation probably prevails in *Cellana radiata* based on homers not dislodging new occupants.

Limited data and observations show that where *Cellana radiata* is abundant, *Siphonaria laciniosa* is very low in abundance or absent and

vice versa. This pattern of density distribution often exists at the same vertical level within the midlittoral zone. Whether this indicates interspecific competition between the two limpets remains to be elucidated. In addition, the area occupied by *Cellana radiata* is usually devoid of microalgal grazers other than *Siphonaria laciniosa* and *vice versa*. It would appear, therefore, that competition for food is minimal.

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MEETINGS

Western Society of Malacologists
August 18-21, 1985

The annual meeting of the Western Society of Malacologists will be held on the campus of the University of California, Santa Barbara. The main emphasis will be on the molluscan fauna of the Eastern Pacific with sessions including land snails, paleontology, etc. There will also be a symposium on Hawaiian mollusks chaired by Mrs. Beatrice Burch.

Anyone interested in pre-registration or call for papers please contact William D. Pitt, president, WSM, 2444 38th Ave., Sacramento, CA 95822. Telephone (916) 428-3899, home evenings.

DEATHS

Joseph Rosewater, 1928 - 1985

Joseph Rosewater, Curator of Mollusks at the U.S. National Museum since 1960, a past-President of the American Malacological Union, and a long-time contributor to *The Nautilus*, died after a relatively short illness on March 22, 1985, in Washington, DC, at the age of 56. He is survived by a son, two daughters and his widow, Mary Carlson Rosewater, 818 Woodley Drive, Rockville, MD 20850. An obituary and list of his publications will appear in the joint Clench-Rosewater memorial issues of the 100th Anniversary volume of *The Nautilus* in 1986. We are informed that a fellowship fund for visiting mollusk students will be set up at the Smithsonian Institution in memory of Dr. Rosewater.

THE LAND SNAIL FAMILY HYDROCENIDAE IN VANUATU (NEW HEBRIDES ISLANDS), AND COMMENTS ON OTHER PACIFIC ISLAND SPECIES

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ABSTRACT

Georissa obsoleta *new species (Gastropoda, Prosobranchia, Archeogastropoda, Hydrocenidae) is described from Efate Island, Republic of Vanuatu. It is characterized by its minute size, obsolete sculpture, channelled suture, and conical form. It is the first record of Hydrocenidae from Vanuatu. Relationships with other Pacific species are not clear. The Hawaiian* Georissa neili *Pilsbry, 1928 is synonymized with* G. cookei *Pilsbry, 1928.* G. kauaiensis *Pilsbry, 1928 (Hawaiian Islands),* Chondrella striata *Pease, 1871 (Cook Islands), and* Cyclostoma minutissima *Sowerby, 1832 (Pitcairn Island) are based on juvenile specimens but appear to be* Georissa.

Key words: land snails, Hydrocenidae, Georissa obsoleta, *Pacific Islands, Vanuatu, New Hebrides Islands, Efate Island.*

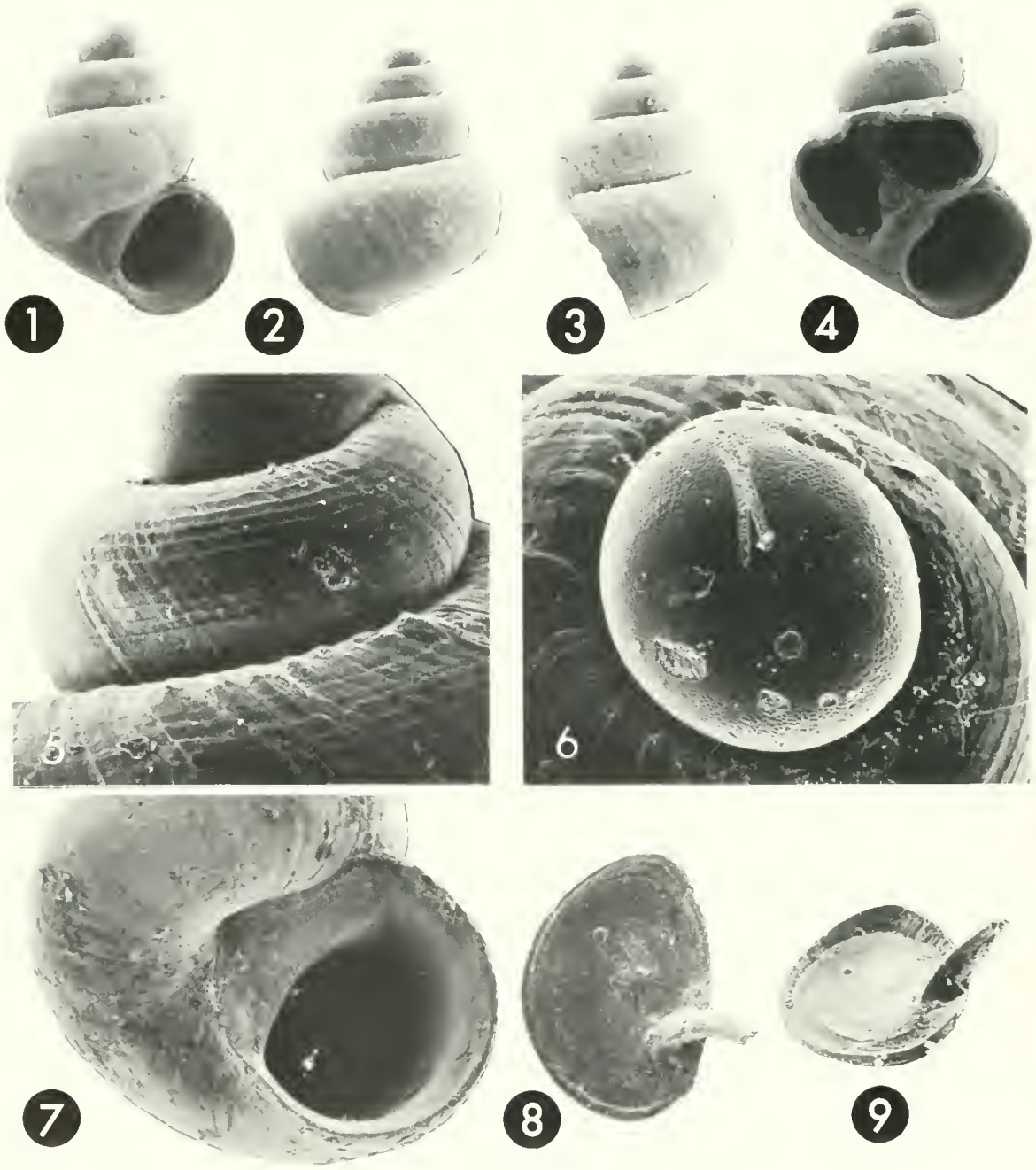
During June-August, 1984 the junior author had the opportunity to visit the Republic of Vanuatu, formerly called the New Hebrides Islands. Significant collections of land snails were made on Efate, Erromango, and Tanna. The collections are particularly interesting because of the large number of minute species that were recovered from leaf-litter samples gathered at many stations. A species of particular interest to us is described below. It is the first record of the family Hydrocenidae from Vanuatu.

Hydrocenid land snails are widely deployed on Pacific islands, Japan, New Zealand, Australia, the Indo-Australian archipellago, Southeast Asia, Madagascar, Africa, and Mediterranean Europe. They are poorly known because of their minute size and cryptic behavior, although they may be locally abundant (Thompson and Dance, 1983). Most species are confined to limestone substrates and encrust their shells with lime or mud. Live specimens appear more like minute blobs of dirt than like coiled shells. Thus, it is not surprising that this family was not reported in the two principal papers on the New Hebrides fauna (Solem, 1959, 1962). Because the new species has very poorly developed shell sculpture we name it:

Georissa obsoleta

Thompson and Huck, *new species*

Shell (Figs. 1-7): Minute, adults about 1.7-1.9 mm long, about 0.72-0.78 times as wide as high. Color varying from yellow-gray to fulvous in fresh shells. Conical with a wide rounded apex; consisting of 3.3-3.7 whorls. Apex rounded, with a large cap-shaped protoconch consisting of 1.3 whorls (Fig. 6). Protoconch sculptured with a dense mesh of minute pits. Suture between whorls of teleoconch very deeply impressed, forming a channel around middle of shell (Fig. 5). Sculpture of teleoconch consisting of very weakly developed spiral threads that form an obsolete cancellate pattern where they cross growth striations and threads (Fig. 2). Growth threads tend to be enlarged above shoulder of whorl and usually form weak denticles along second and third whorls (Fig. 5). Aperture ovate in shape, about as wide as or slightly wider than high; about 0.39-0.48 times length of shell. Parietal wall nearly straight, lying at an angle of 30-32° to axis of shell (30° in holotype); plane of aperture at 20-25° to shell axis (Fig. 3). Umbilical area with a wide shield that is indented along outer edge (Fig. 7). Parietal septum extending into shell for ¾ whorl, where upon the earlier septum has been readsorbed (Fig. 4).



FIGS. 1-9. *Georissa obsoleta* Thompson and Huck, new species. **1**, UF 50628a (×31). **2**, UF 50629a (×31). **3**, UF 50629a (×31). **4**, UF 50627 (×31). **5**, UF 50628b (×164). **6**, UF 50628b (×205). **7**, UF 50628a (×62). **8**, inner surface of operculum (×82). **9**, oblique view of operculum at 70° from base (×82).

Measurements for the holotype and five paratypes (UF 50633) selected to show variation follow:

	length	width	apert. h	apert. w	whorls
holotype	1.64	1.24	0.74	0.74	3.6
paratype	1.89	1.40	0.76	0.87	3.7
paratype	1.80	1.40	0.84	0.84	3.6
paratype	1.71	1.27	0.74	0.74	3.5
paratype	1.61	1.24	0.74	0.74	3.1

Operculum (Figs. 8, 9): Calcareous, concentric with a large subcentral nucleus. Inner surface with a long slender peg along columellar margin. Peg lying at a relatively low angle to plane of operculum; dorso-ventrally flattened; base of peg extending out to columellar edge of operculum. Innter surface of operculum flat, with a narrow raised callus around edge (Fig. 8), but not to the extent that occurs in *Chondrella parva* (Pease, 1864).

Type locality: Vanuatu, Efate Island, above Mele village along trail to the cascades, 75 m altitude. *Holotype:* UF 50631; collected 23 June 1984 by Emilye L. Huck. Paratypes: UF 50632 (57), UF 50633 (13 measured specimens), UF 50634 (11), UF 50627 (1 gold plated), UF 50628 (2 gold plated), UF 20629 (2 gold plated), Bernice P. Bishop Museum 207565 (6), Australian Museum C144145 (5), Rijksmuseum van Natuurlijke Historie 55724 (5); same locality as holotype.

The type series was collected from leaf-litter samples gathered at the base of a limestone knoll at the edge of a banana grove in a dense rain forest, along the cascades of a small river near Mele village. Most of the specimens are slightly weathered. A few specimens are in fresh condition and retain the natural color. The holotype is a slightly immature specimen selected because it is the freshest specimen in the lot, it shows details of sculpture and color and the operculum is retained within the aperture. The paratypes illustrated in Figs. 1, 2 (UF 50628a) are nearly identical to the holotype but are very slightly larger. The figured operculum was recovered from a paratype (UF 50632).

Discussion

Georissa obsoleta is characterized by its minute size, its moderately wide, conical form, its channelled suture, and its sculpture. These features distinguish the species from all other known Pacific *Georissa*. Five other species are described as being smaller, but their original descriptions appear to be based on juveniles and better material has not been reported.

It is difficult to determine specific relationships because very little is known about the Pacific Hydrocenidae. Six species have been described from the northern and eastern Pacific. Three are recorded from Kauai, Hawaiian Islands, *Georissa cookei* Pilsbry, 1928, *G. neili* Pilsbry, 1928, and *G. kauaiensis* Pilsbry, 1928. The three were recovered from moss samples collected from fallen logs on a ridge between Hanalei and Wailua. The type specimens of all three are juveniles, and each is known from only one or two specimens. On the basis of variation that we have seen in other species (*see* Thompson and Dance, 1983) we suspect that *G. cookei* and *G. neili* are the same species, and we have little faith in the distinction of *G. kauaiensis*. Regardless of their specific status, their juvenile shells do not permit comparisons with other species because definitive characteristics of size, shape, sculpture and whorl development cannot be determined.

One species is known from the Cook Islands, *Chondrella striata* Pease, 1871, and one is described from Pitcairn Island, *Cyclostoma minutissima* Sowerby, 1832. Both appear to be typical *Georissa* and both are based on juvenile shells. Thus it is not possible to discuss their characteristics for the purpose of specific comparisons, other than to say that they are sculptured more heavily than is *G. obsoleta*.

Another species is recorded from the Society Islands, *Cyclostoma parva* Pease, 1864. It is much larger and smoother than *G. obsoleta*, and is placed in a separate genus, *Chondrella*, because of a heavy callused ridge around the inside margin of the operculum.

Other species are known from New Zealand, Australia, and islands to the north, but close relationships between *G. obsoleta* and these are not apparent.

Acknowledgments

The junior author traveled to the Republic of Vanuatu (New Hebrides Islands) assisted by a grant provided by The Explorers Club Educa-

tion and Youth Activities Fund and the Haverlee Exploration Fund of the Central Florida Chapter of The Explorers Club. We wish to express our gratitude to the society for this aid, and to Dr. R. Tucker Abbott for his encouragement. She was accompanied in the field by her mother, Robin B. Huck. Harvey A. Miller (University of Central Florida) led the expedition while pursuing studies on Pacific bryophytes under the sponsorship of the National Science Foundation (Grant BSR-8215056). The SEM micrographs comprising the illustrations in this paper were prepared by Kurt Auffenberg (Florida State Museum) from the HITACHI S415A Scanning Electron Microscope in the Department of Zoology, University of Florida. George M. Davis (Academy of Natural Sciences, Philadelphia) loaned us specimens of *Cyclostoma parva* Pease for comparison. A discussion of its specific and generic status will be presented elsewhere by the senior author. We wish to express our gratitude to all people who have assisted us in this study.

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COMMENTS ON THE DISTRIBUTION OF FRESHWATER MUSSELS (UNIONACEA) OF THE POTOMAC RIVER HEADWATERS IN WEST VIRGINIA

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ABSTRACT

This report presents data collected in 1981 and 1984 on the mussels of the upper Potomac River located within the eastern panhandle of West Virginia. My data indicate that North Branch is devoid of mussels apparently as a result of extensive strip mining; South Branch has a small but healthy mussel population. The Cacapon River and Patterson Creek, tributaries to the Potomac, also have viable populations. Eight species of mussels were found in the Potomac headwaters. Elliptio complanata, E. fisheriana *and* Lampsilis ventricosa *were fairly common and* Alasmidonta varicosa, A. undulata, Anodonta cataracta, Strophitus undulatus, *and* Lasmigona subviridis *were uncommon throughout the system.* Corbicula fluminea *was found throughout the drainage with the exception of North Branch.*

The freshwater mussel fauna of the Potomac River headwaters is virtually unknown. Ortmann (1919) has done the only previous extensive collecting in the region, and that was completed around the turn of the twentieth century. He probably took a train to Romney, West Virginia, and then to Harpers Ferry to collect in the Potomac River over a distance that could be

covered in a day's ride by buggy. All of his records are in the immediate area of these two towns. Johnson (1970) reported that Carol Stein did limited collecting at Harpers Ferry in the early sixties. I can find no evidence of other work having been done in the upper Potomac River.

The reasons for the paucity of work there include: very poor roads (until recently) into the area; a very difficult terrain to maneuver; and limited access to the river at any point.

Clarke (1981), Johnson (1970), and Ortmann (1919) all indicated a depauperate assemblage of mussels in this stream. My report does not dispel those findings. There are small populations present but they are widely spread and occur more often in the smaller tributaries than in the main trunk of the river. The only population of considerable size that I found was located at an area locally known as Pack Horse Ford, just downstream of Sheperdstown, West Virginia. All other areas reported herein represent small populations of no more than a couple of dozen specimens from any one site.

The Potomac River originates in the Potomac highlands in the eastern panhandle of West Virginia. The mainstem Potomac River then continues along the Maryland/West Virginia border for Ca. 160 km to Harpers Ferry where it receives the Shenandoah River which has its headwaters in Virginia. I have not collected below Harpers Ferry. Two other major tributaries in West Virginia are the Cacapon River and Patterson Creek (Fig. 1).

Ortmann (1919) collected in the South Branch Potomac River at Romney and Southbranch and reported the following species: *Elliptio complanata* (Lightfoot, 1786), *Lasmigona subviridis* (Conrad, 1835), *Anodonta cataracta* Say, 1817, *Strophitus undulatus* (Say, 1817) and *Alasmidonta varicosa* (Lamarck, 1819). He also reported *E. complanata* and *A. varicosa* from the Shenandoah River at Harpers Ferry. Clarke (1981) reported *Alasmidonta undulata* (Say, 1817) from the South Branch and Shenandoah rivers and *A. varicosa* from Cherry Run and Lost River, a small tributary of the Cacapon River. Johnson (1970) reported two additional: *Lampsilis ventricosa* (Barnes, 1823) and *Elliptio fisheriana* (Lea, 1838) [=*lanceolata* (Lea, 1820)]. The Cacapon River and Back Creek are

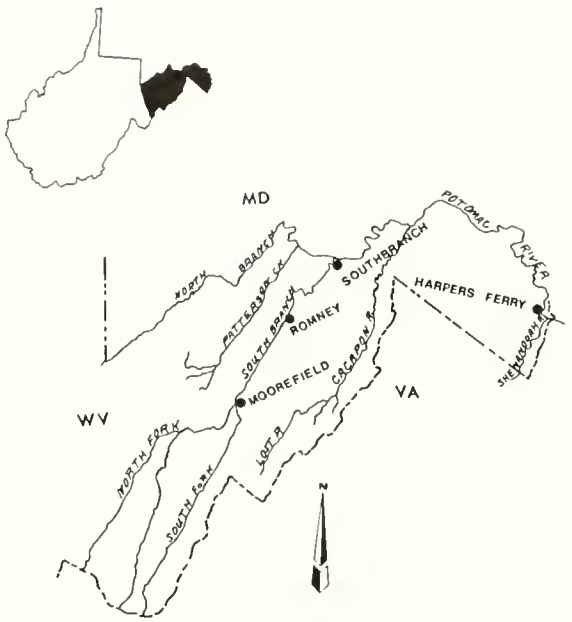

FIG. 1. Headwaters of the upper Potomac River.

listed as the localities where these two mussels were collected.

My collecting was done during the summers of 1981 and 1984. Collecting involved wading the streams and collecting specimens that had been observed through the use of a glass-bottomed viewbox (waterscope). The entire drainage was covered to the extent that it was practical. Many areas are virtually inaccessible and could be reached only by raft or canoe. The sites reported herein are the only ones where mussels were found in any appreciable numbers. At all other localities visited only an occasional isolated individual was seen and seemed not to represent a viable population. Voucher specimens have been placed with the Ohio State University Museum and the Marshall University Malacological Collections.

Collecting Sites

1. Potomac River at Pack Horse Ford, approximately 1 km E of Sheperdstown, Jefferson Co., WV, off County Road (CR) 17/1.

2. South Branch at U. S. Route (US) 50 Bridge, 1 km W of Romney, Hampshire Co., WV.

3. South Branch at Arnold Farm, S of Romney on CR 8/2, 9 km N of Hardy Co. line Hampshire Co., WV.

4. South Branch, off CR 6, N of Village of Cunningham, Hardy Co., WV.

5. South Branch, bridge on US 220 at Petersburg, Grant Co., WV.

6. Cacapon River, off SR 9, 5 km N of Village of Largent, Morgan Co., WV.

7. Cacapon River, along CR 15 at public fishing area, Hampshire Co., WV.

8. Cacapon River, 1.5 km S of Village of Capon Bridge on CR 14, Hampshire Co., WV.

9. Cacapon River at bridge on CR 9/12, Morgan Co., WV.

10. North River of Cacapon River, along Delray Road (=CR 11), Hampshire Co., WV.

11. Patterson Creek, along CR 46 near Fort Ashby, Mineral Co., WV.

12. Patterson Creek, at intersection of CR 28/3 and CR 28/10, Mineral Co., WV.

13. Shenandoah River, at Harpers Ferry, Jefferson Co., WV.

Discussion

There are areas in the headwaters of the Potomac River drainage where small populations of naiads still persist. The North Branch of the Potomac River, however, has no detectable mussel population. All the collecting sites showed signs of mining damage. The substratum was covered with heavy deposits of ochre indicating the presence of mining effluent. *Corbicula fluminea* (Müller, 1774) which was found everywhere else in the drainage, was not found in this major tributary of the Potomac. The rest of the headwaters showed little evidence of disturbance by man. Presently, most of the area is fairly pristine with no industry or logging activities. Farming centers around the production of apples so there is little stream siltation.

Species Accounts

Elliptio complanata: This species was the most commonly found species in the study area and was found at nearly every collection site.

Elliptio fisheriana: Johnson (1970) stated that this may simply represent a northern form of *Elliptio lanceolata*. *E. fisheriana* is, however, being recognized by the committee of the American Malacological Union which is currently preparing a list of generally accepted names for the naiads. While never found in abundance, it is widespread throughout the headwaters.

Lampsilis ventricosa: This species is normally an interior basin species. It was inadvertently introduced into the Atlantic drainage about the turn of the century. It has become well established and is quite common throughout much of the drainage. It has apparently replaced the resident species *Lampsilis cariosa* (Say, 1817) in the upper Potomac River. The Ohio State University Museum of Zoology has several specimens of *L. cariosa* from the lower Potomac

TABLE 1. Distribution of naiad mussels in the headwaters of the Potomac River system by species.

	Site Number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Elliptio complanata	X			X	X	X	X	X	X	X	X	X	
Elliptio fisheriana	X					X			X			X	
Lampsilis ventricosa	X	X	X	X		X			X			X	X
Alasmidonta varicosa	X		X	X		X						X	
Alasmidonta undulata				X								X	
Anodonta cataracta	X				X								
Lasmigona subviridis	X		X									X	
Strophitus undulatus												X	X

but none from this reach (Stansbery, 1984, pers. comm.).

Alasmidonta varicosa: Apparently fairly common throughout the headwaters. Widespread throughout the Atlantic coastal drainages.

Alasmidonta undulata: This species is apparently quite rare here as only five specimens were found. Widespread throughout the Atlantic coastal drainages.

Anodonta cataracta: This species does not exhibit a widespread distribution in the headwaters. It is typically found in larger, slower-flowing bodies of water. Only four specimens were found during this study.

Lasmigona subviridis: This small species may be more abundant than my collections indicate. It is a typical Atlantic coastal species and enjoys a widespread distribution in most of eastern North America. It has crossed the mountain barrier on at least one occasion and can be found in the New River system (a tributary of the Ohio River) of southern West Virginia. One specimen was found at each of three different collecting stations during this study.

Strophitus undulatus: This species is not common. Ortmann (1919) reported it only from South Branch at Romney. I found a single live specimen in Patterson Creek and a badly-weathered half shell in the Shenandoah River.

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A SECOND MELAMPID (PULMONATA: BASOMMATOPHORA) FROM THE EARLY MIOCENE OF VENEZUELA

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ABSTRACT

Pedipes *cf.* P. mirabilis *(Mühlfeld, 1816) was reported by the present authors (1979, p. 22) from the early Miocene (Burdigalian) Cantaure Formation, Paraguaná Peninsula, Venezuela, being the first reported fossil occurrence of the genus. It is described now as the new species* Pedipes mirandus *and is considered to be the ancestor of the Recent cognate species* P. angulatus *C. B. Adams, 1852, from the Eastern Pacific and* P. mirabilis *from the Western Atlantic.*

The presence in the early Miocene (Burdigalian) Cantaure Formation, Paraguaná Peninsula, Venezuela, of two members of the family Melampidae was reported by Gibson-Smith & Gibson-Smith (1979, p. 22). One of these, *Tralia* cf. *T. ovula* (Bruguière, 1789), was later described by these authors (1982, p. 119) as the new species *T. venezuelana,* which lives along the north coast of Venezuela, occurring also in the late Pliocene Mare Formation, Cabo Blanco, Venezuela. This was only the second fossil record of the genus *Tralia* the other being *T. vetula* Woodring, 1928, from the Pliocene Bowden Formation, Jamaica. The second Cantaure form, *Pedipes* cf. *P. mirabilis* (Mühlfeld, 1816), the first fossil record of the genus, is likewise now recognized as a new species, *Pedipes mirandus.* It is considered to be the ancestor of the Recent cognate species *P. angulatus* C. B. Adams, 1852, from the Eastern Pacific and *P. mirabilis* from the Western Atlantic. The genus was reviewed by Clench

(1964, p. 119) and the only other Recent taxa of the region are *P. liratus* Binney, 1860, and *P. unisulcatus* Carpenter, 1866, both from the Eastern Pacific.

The author of *Pedipes* was said by both Clench (loc. cit.) and Keen (1971, p. 848) to be Férussac, 1821, the former giving the type species as, "*Pedipes afra* Gmelin (=*P. pedipes* Bruguière), subsequent designation, Gray 1847." Abbott (1974, p. 333), on the other hand, gave the author as Bruguière, 1792, with type species [*Helix*] *afer* Gmelin. According to Clench (loc. cit.) *afer* is a Pfeiffer, 1856, misspelling of *afra*. Zilch (1959, p. 68) was the first to name Bruguière, 1792, as the author, the type species being *Bulimus pedipes* Bruguière, 1789, by tautonymy.

Subfamily Pedipedinae Crosse & Fischer, 1880

Genus *Pedipes* Bruguière, 1792

Type species, by tautonymy, *Bulimus pedipes* Bruguière, 1789.

Pedipes mirandus
Gibson-Smith & Gibson-Smith, n. sp.
Figure 1

Description: Shell minute. Protoconch heterostrophic, submerged, last ½-whorl inclined, smooth. Teleoconch of 3¼ shouldered whorls, body whorl globose. Sculpture of flat, subequal spiral cords with narrower interspaces, subsutural cord prominent; 4 cords between it and the shoulder and about 23 below. Surface roughened by crowded, prosocline growth incrementals. Columella broad, inclined, with two inclined folds, the lower the weaker. Parietal callus narrow, carrying a large fold lying closer to the anal notch than to the upper columellar fold. Outer lip thin, smooth within.

Holotype: Natural History Museum Basel, No. H 17113. Height 2.25 mm, diameter 1.75 mm. *Type locality:* Known only from the lower shell-bed of the early Miocene Cantaure Formation, Paraguaná Peninsula, Venezuela (GS-1-PGNA). *Paratype:* Paleontological Research Institution, PRI 30049.

Remarks: The type material consists of 5 small, complete specimens and, in the absence of even fragments of larger shells, are believed to be mature. While the absence of a labral denticle might suggest immaturity it is not a characteristic of all mature *Pedipes*, the equally small *P. liratus* also lacking a denticle (Keen, 1971, fig. 2411). Comparison has been made with juvenile *P. mirabilis* of a similar size. The trivial name is from the same Latin root as *mirabilis* meaning "wonderful" or "singular".

FIG. 1. *Pedipes mirandus* n. sp. Holotype, ventral view. Height 2.25 mm, diameter 1.75 mm. Early Miocene Cantaure Formation, Paraguaná Peninsula, Venezuela. NHMB H 17113. SEM micrograph, ×25.

Comparisons: P. mirandus n. sp. is most closely related to *P. angulatus* and *P. mirabilis*, the sculpture and outline being similar. In its broad columella it more resembles *P. angulatus* and in the reduced extent of the parietal callus it more resembles *P. mirabilis*. It differs from both in being smaller with 1 or 2 fewer whorls, in having an inclined columella and inclined columellar folds, the lower smaller than the upper; in *P. angulatus* and *P. mirabilis* the columella is vertical, the folds are about equal in size and are horizontal. In both of these, moreover, the parietal folds lies midway between the upper columellar fold and the anal notch, whereas in *P. mirandus* the fold lies closer to the anal notch, dividing the gap into one-third and two-thirds, and it is more horizontally directed.

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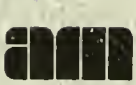

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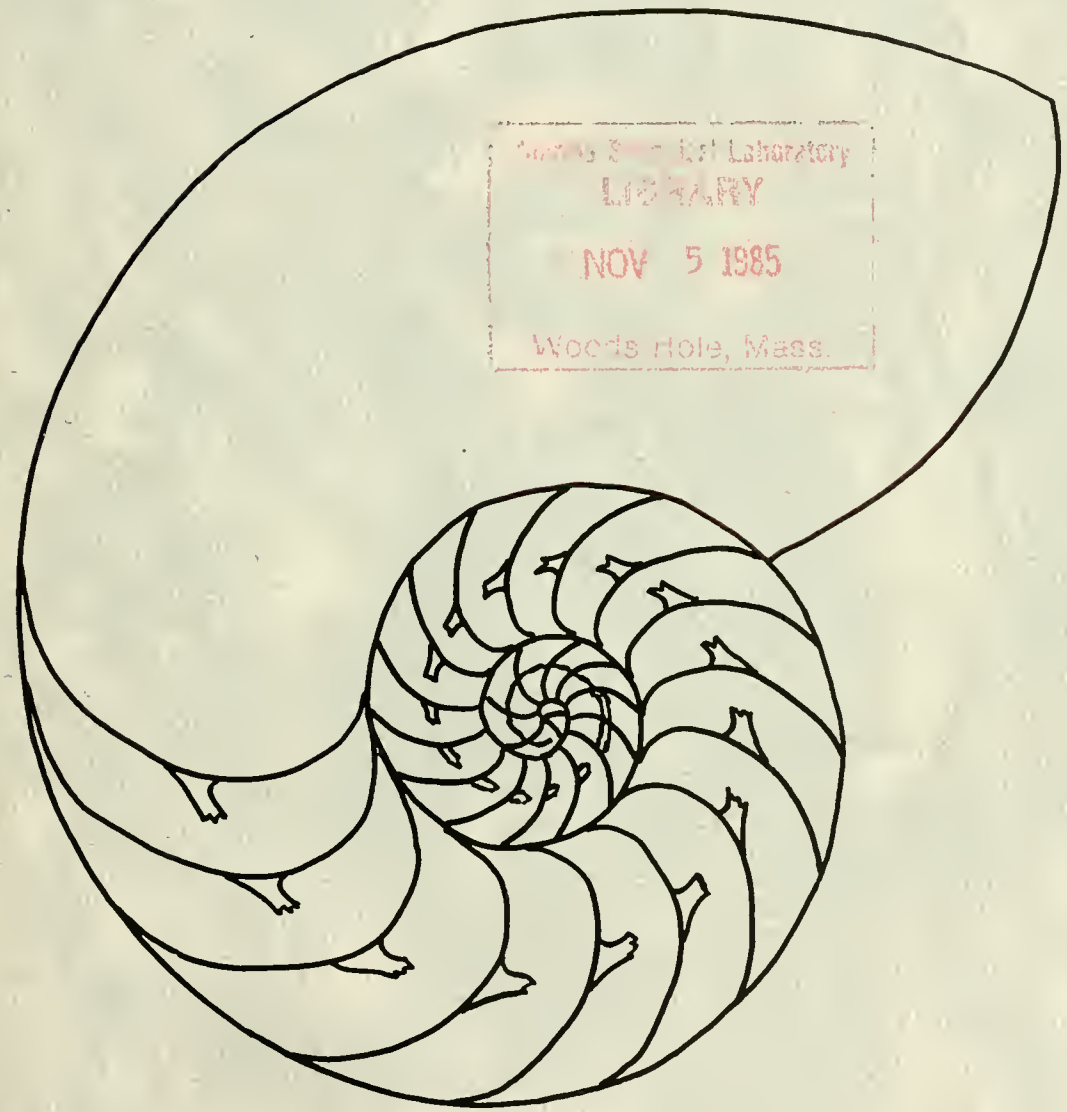

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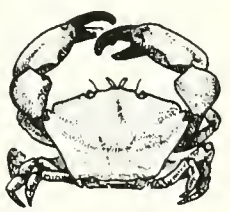

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THREE NEW DEEP-WATER INDO-PACIFIC AND ONE INTERTIDAL BRAZILIAN SPECIES OF *TEREBRA* (GASTROPODA)

Twila Bratcher
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Hollywood, CA 90046

and

Walter O. Cernohorsky
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Auckland, New Zealand

In 1982 on cruise 32 of R.V "Marion-Dufresne", under the direction of Dr. A. Guille, terebrid specimens were dredged from fifteen stations off Reunion Island in the Indian Ocean. On board were malacologists Dr. Philippe Bouchet, A. H. Waren, and B. Metivier. Two species new to science were dredged along with several uncommon species. Among them were *Hastula celidonota* (Melville & Sykes, 1898), the only member of the genus with a dark dorsal splotch; *Terebra virgo* Schepman, 1913, a species with a white shell somewhat resembling *T. funiculata* Hinds, 1844; a range extension of *Terebra mactanensis* Bratcher and Cernohorsky, 1982 (the white color form). Those from Reunion Island differ from the typical form by having regular yellowish brown dots between the ribs on the subsutural band while those of the typical form are scattered irregularly. All the specimens mentioned above are in the collection of the Muséum National d'Histoire Naturelle of Paris.

A large new terebrid species, 97.6 × 14.4 mm, was dredged off the coast of Natal, South Africa, in 1983. The eastern continental shelf off South Africa, where this species was found, has barely been studied. The shelf was last dredged in 1901, other than incidental hauls made by Dr. R. N. Kilburn of the Natal Museum and Dr. Allan Connell. (Dr. R. N. Kilburn, *pers. comm.*) This no doubt is the explanation of why so large a species has remained undiscovered until the present time.

The third new species is from the Western Atlantic and has been collected intertidally to 30 m. It has been misidentified by dealers and others as *T. doellojuradoi* Carcelles, 1953.

Family **Terebridae** Mörch, 1852
Terebra Bruguière, 1789

Terebra Bruguière, Encycl. Meth. Hist. Nat. Vers 1:xv. *Type species* by SD (Lamarck, 1799): *Buccinum subulatum* Linnaeus, 1767. Recent; Indo-Pacific.

Terebra pseudopertusa
Bratcher & Cernohorsky, *sp. nov.*
(Figs. 4, 5)

Diagnosis: A terebrid similar to *Terebra pertusa* (Born, 1778), but with the shell having mamillate protoconch and an extra row of squarish, brown maculations below the subsutural band and at the periphery of the body whorl.

Description: Shell shiny, of moderate size for the genus with 13 whorls in the teleoconch; protoconch of 1½ mamillate whorls; outline of whorls straight; subsutural band defined by a groove and with punctations between the ribs; axial ribs sharp, 15 on penultimate whorl, with wide interspaces; interspaces with 5 spiral grooves not crossing ribs; body whorl with ribs fading out at periphery, smooth below; aperture quadrate; columella slightly recurved; color yellowish with dark-brown maculations between white-topped ribs on the subsutural band and at the periphery of the body whorl.

Dimensions: Holotype 36.1 × 6.2 mm; paratypes from 10.4 × 2.4 to 36.2 × 6.3 mm.

Type Locality: Reunion Is., Indian Ocean (21°06′S, 55°01″E) at 80-83 m depth.

Type Material: Holotype and 6 paratypes in MNHNP; 1 paratype in the Bratcher collection.

Distribution: From South Africa to Papua New Guinea, in depths to 110 m.

Discussion: This species was originally thought to be a color form of *T. pertusa* (Born, 1778), until a specimen was examined with its mamillate protoconch intact. All specimens with the extra row of maculations subsequently examined also posessed paucispiral protoconchs. *T. pertusa* has a multispiral protoconch, always lacks the additional rows of maculations, and grows to a much larger size (97.5 mm) than any specimens of this species examined.

FIGS. 1-6. **1**, *Terebra riosi* Bratcher & Cernohorsky, new species. Holotype LACM no. 1974. 9.8 × 2.5 mm. **2** and **6**, *Terebra connelli* Bratcher & Cernohorsky, new species. Holotype Natal Museum no. C4715. 97.6 × 14.4 mm. **3**, *Terebra reunionensis* Bratcher & Cernohorsky, new species. Holotype MNHNP. 13.2 × 2.2 mm. **4** and **5**, *Terebra pseudopertusa* Bratcher & Cernohorsky, new species. Holotype MNHNP. 36.1 × 6.2 mm.

Terebra reunionensis
Bratcher & Cernohorsky, *sp. nov.*
(Fig. 3)

Diagnosis: A small slender brown terebrid with no subsutural band and with numerous thin riblets.

Description: Shell small, slender, with 18 whorls in the teleoconch; protoconch of 3 conical whorls; outline of whorls flat; no subsutural band; axial ribs faintly curved, equal to the width of the interspaces, extending from suture to suture, 18 on penultimate whorl; spiral threads in interspaces numerous, 10 on penultimate whorl, lightly crossing ribs, fading below periphery of body whorl; aperture elongate; columella slightly curved; color light brownish beige.

Dimensions: Holotype 13.2 × 2.2 mm; paratypes 13.6 × 2.5 mm and 12.7 × 2.5 mm.

Type Locality: Reunion Island, Indian Ocean (21°05′S, 55°12′E), in depths of 170-225 m.

Type Material: Holotype and one paratype in the MNHNP; one paratype in the Bratcher coll.

Distribution: Reunion Island, Indian Ocean, in depths of 110 to 225 m.

Discussion: This is one of the most slender of the small Indo-Pacific terebrids. *Terebra contracta* (E. A. Smith, 1873) may be separated from this species by its brown aperture and columella, its turrited outline and more elongate body whorl.

There is little variation in the three specimens of this species which were collected from two localities at Reunion, except that the spiral threads on one specimen are missing from the anterior third of the last three whorls only.

Terebra connelli
Bratcher & Cernohorsky, *sp. nov.*
(Figs. 2 and 6)

Diagnosis: A beige and brown terebrid with no spiral sculpture except for a deep subsutural groove, and with heavy, crowded posteriorly protracted axial ribs both on subsutural band and remainder of whorl.

Description: Shell robust, large for the genus (97.6 mm, nearly 4 inches), with 28 whorls remaining, apex missing; outline of whorls shouldered below convex subsutural band; band with round nodes on early whorls, becoming strong ribs later, occupying about ⅓ of the whorl, defined below by a moderately deep groove; axial ribs on remainder of whorl rounded, strong, crowded, the same strength and width as those on band, straight on early whorls, curved later, 31 on penultimate whorl; spiral sculpture absent except for a narrow, fine cord below the axial ribs immediately above the suture; body whorl short, with ribs ending abruptly at periphery; aperture quadrate; columella recurved; siphonal fasciole striate, defined by a keel; color brownish beige stained with darker areas and with a nebulous brown area anterior to periphery of body whorl.

Dimensions: Holotype 97.6 × 14.4 mm; paratype 50.5 × 9.0 mm.

Type Locality: Off Umhlanga Rocks, Natal, South Africa, 116 m depth.

Type Material: Holotype Natal Museum no. B6307; paratype Natal Museum no. C4715.

Distribution: Natal, South Africa.

Discussion: In both specimens the ribs on the band and remainder of the whorl have the appearance of polished antique ivory. The only species with which this can be compared is *Terebra pretiosa* Reeve, 1842, which also has numerous heavy ribs, but that species has longer whorls, a flatter subsutural band defined by deep punctations, and its color is yellowish beige marked with dark-brown maculations.

This species is named in honor of Dr. Allan Connell, who dredged the holotype.

Terebra riosi
Bratcher & Cernohorsky, *sp.nov.*
(Fig. 1)

Diagnosis: A very small, cream-colored Western Atlantic terebrid with purplish brown anterior to the periphery of the body whorl and a purple-brown subsutural line.

Synonymy:
1984 *Terebra doellojuradoi* Carcelles, Aubry, Terebridae pl. 9, upper left [not Carcelles, 1953].

Description: Shell very small (8 to 10 mm) for the genus with 8 teleoconch whorls plus a protoconch of 3½ amber, conical whorls; outline of whorls faintly turreted; subsutural band marked only by a nebulous purplish brown line on early whorls, 2 rows of weak nodes with the nebulous line in the center appearing later; no subsutural groove; axial ribs sharp, narrower than interspaces, in early whorls unbroken from suture to

suture, subsutural nodes developing later, 15 on penultimate whorl; fine spiral grooves evenly spaced, 5 on penultimate whorl, not crossing summit of ribs; body whorl with axial ribs ending at periphery, spiral grooves continuing to siphonal fasciole, aperture quadrate; columella brown, slightly curved; color yellowish cream, almost transluscent, with a nebulous purplish brown subsutural line which appears to be under translucent enamel, light purplish brown anterior to periphery of body whorl; columella dark-brown.

Dimensions: Holotype 9.8 × 2.5 mm; paratypes from 8.1 × 2.3 mm to 10.2 × 2.6 mm.

Type Locality: Buzios, Cabo Frio, Rio de Janeiro, Brazil, intertidal in sand.

Type Material: Holotype Los Angeles County Museum of Natural History no. 1974; 3 paratypes Museu Oceanografico de Rio Grande no 21.278; 1 paratype Bratcher coll.

Distribution: Atlantic coast of central Brazil, intertidal to 30 m.

Discussion: This species has been misidentified by dealers and Aubry (1984) as *Terebera doellojuradoi* Carcelles, 1953, which has a protoconch of 1½ whorls, a teleoconch with cancellate sculpture, a subsutural band marked by punctations or square pits between the ribs, and no brownish subsutural line nor brownish area below the periphery of the body whorl.

This species is named in honor of Prof. E. C. Rios of Brazil, who first brought it to our attention.

Acknowledgments

We wish to thank Dr. Philippe Bouchet of the Muséum National d'Histoire Naturelle de Paris, Dr. Richard Kilburn of the Natal Museum of South Africa, and Prof. E. C. Rios, Museu Oceanografico de Rio Grande, Brazil, for the loan of material for this study.

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SUCCINEA VAGINACONTORTA LEE (GASTROPODA: PULMONATA: SUCCINEIDAE)

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ABSTRACT

On the bases of shell characters, geographic distribution, and habitats Succinea vaginacontorta *Lee is a valid species and not a synonym of* Succinea indiana *Pilsbry.*

Synonymy:

Succinea vaginacontorta Lee, 1951, Occas. Pap. Mus. Zool. Univ. Mich. No. 533, 1-7, pl. 2, text fig. 1; Miles, 1958, Univ. Kans. Sci. Bull. Vol. XXXVIII, Pt. II, No. 24, 1517-1519, Pl. IC, fig. 4; Leonard, 1959, Handbook of Gastropods in Kansas, Mus. Nat. Hist. Misc. Pub. 20, 155-158, pl. 9, fig. 3; Franzen, 1971, Nautilus 84(4), 131-142, tables 2, figs. 3.

Succinea indiana Pilsbry, Hubricht, 1961, Nautilus 72(2), insert in reprint, p. 60.

Succinea indiana Pilsbry, Hubricht, 1985, Fieldiana Pub. No. 1359: 15, Map p. 117.

The employment of anatomical structures of soft parts, radulae, pigmentation patterns as well as shell characteristics is generally essen-

tial for accurate identification of species of Succineidae. Unfortunately, historically, many collectors and authors of species of succineas based their descriptions solely on shell characters. They did not describe, illustrate or preserve the soft parts, therefore, we have to rely on comparisons of shells with those of holotypes and/or paratypes. Some types were catalogued in private collections which in some instances cannot be located.

Pilsbry (1948, p. 818) illustrated the shell and reproductive structures of a succineid which he identified as a *Succinea aurea* Lea from Cape May, New Jersey. The type locality of the species is "Springfield, Ohio." To date I have been unsuccessful in locating the holotype and/or paratypes of *S. aurea* Lea. Pilsbry (*ibid*) placed *Succinea indiana* Pilsbry, 1905, into the synonomy of *S. aurea* Lea. He described only the shell and did not illustrate or describe the soft anatomy of *S. indiana.*

Hubricht collected a live succineid, which he identified as *S. indiana* Pilsbry, from a loess hillside near New Harmony, Indiana, presumably the type locality of the species. "Upon dissection of the animal it was found to be unrelated to *S. aurea* Lea, in the synonomy of which it was later placed by Pilsbry (Pilsbry, 1948). The penis is similar to that of *Succinea campestris* Say, the mantle is dark gray without the spots characteristic of *S. concordialis* Gould. *Succinea indiana* must, therefore, be considered a distinct species belonging to section Calcisuccinea Pilsbry." (Hubricht, 1958, 60-61). Hubricht (1961, 60) reported from a later collection he made from presumably the type locality of *S. indiana,* "A careful examination of the anatomy and shell of topotypes *Succinea indiana* showed no character which could be used to distinguish it from *S. vaginacontorta.* The same twisted vagina is found in *S. indiana. S. vaginacontorta* Lee must be placed in the synonomy of *S. indiana.*"

Pilsbry (1948, p. 817) quotes his 1905 description of *Succinea indiana,* "Shell obesely ovate, thin, brownish amber or raw sienna colored, the apex reddish. Sculpture of fine growth-lines and wrinkles, becoming rather coarse wrinkles on the last half whorl. Whorls 3½, very convex, the last large and inflated. Aperture large, oblique, the outer lip either regularly arcuate or somewhat flattened in the middle. Columella thin and strongly arcuate throughout."

Because soft parts of the holotype and paratypes of *Succinea indiana* Pilsbry have not been described or preserved and, therefore, are not available for examination, comparisons of that species with *S. vaginacontorta* Lee are here based on shell characteristics of the holotype and paratypes of *S. indiana* and topotypes of *S. vaginacontorta,* their habitats and geographic distribution.

Shell Characteristics

Succinea vaginacontorta Lee, section *Calcisuccinea* Pilsbry, 1948. Lee described the shell of the holotype, "Shell is dextral, fully developed. Whorls, 3, with suture only moderately impressed. Whorls which increase proportionately from the apex to the body whorl with no marked discontinuity in size. In life shell is a dull, translucent, light, horn yellow with greenish tones. Striae present and well raised (Pl. 1, Fig. 3). Epidermis of upper whorl eroded away revealing dull white deeper layers of shell, parietal wall with well-developed callus, covering base of slightly curved columella (Pl. 1, Fig. 2). Aperture obliquely ovate with a slight flare at base of outer lip. Interior of aperture with a thin shiny transparent sheen." (Lee, 1951, 3).

Significant shell differences of the two species can be noted in Fig. 1, and are here listed:

1. *Succinea vaginacontorta* is more elongate-ovate than *S. indiana. S. vaginacontorta* attains a height up to 12.3 mm (Franzen, 1971, Table I). Height of holotype of *S. indiana,* 11.0 mm.
2. Nuclear whorl of both species knob-like; that of *S. vaginacontorta* large and more prominent; of *S. indiana* reddish brown.
3. Spire of *S. vaginacontorta* more tightly twisted and acute-elongate than of *S. indiana.* First whorl of *S. vaginacontorta* larger than of *S. indiana.*
4. Whorls of *S. indiana* more inflated and shouldered; body whorl more inflated, roundly ovate and aperture more elongate-ovate than of *S. vaginacontorta.*
5. Peristome of *S. vaginacontorta* sharp, continuous as a well-developed callus on body wall and covering the columella as it ascends. Columella of *S. indiana* white, recurving as it disappears into ultimate whorl; callus on body wall thin.
6. Periostracum of *S. vaginacontorta* thin, dull, light horn yellow, readily removable exposing the deeper, white layers of the shell. Striae heavier and coarser than of *S. indiana* which produce a rough appearance on surface of ultimate whorl. Due to the heavy striations the shell, when stripped of its periostracum, has a striped appearance. Periostracum of *S. indiana* yellow-amber, doesn't

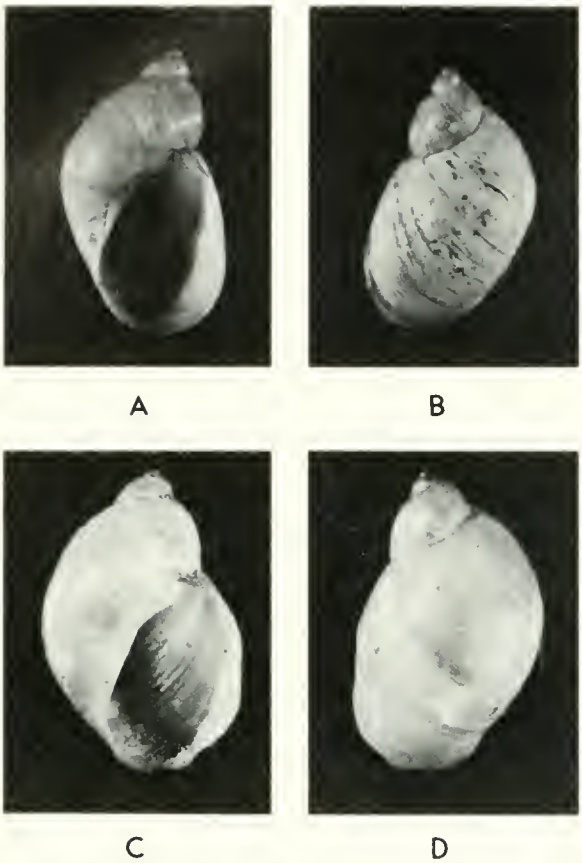

FIG. 1. **A, B.** Topotype of *Succinea vaginacontorta* Lee. Height, 10.7 mm. **C, D.** Holotype of *Succinea indiana* Pilsbry. Height, 11.0 mm.

peel as readily as of *S. vaginacontorta;* striae fine resulting in a shiny, silky surface.

Habitats and Geographic Distribution

Type locality of *Succinea vaginacontorta* Lee, SW corner of S 18, T 33 S, R 28 W, Meade County, Kansas, ". . . a sagebrush flat on which hairy gramma grass (*Bouteloua hirsuta* Lag.) was growing along a small creek . . . It is not subject to flood. The nearest permanent water is Crooked Creek about one-half mile to the east. The hairy gramma grass occurred in thick stands with a few small patches between the stands. The snails lived on spots of lichens, mosses, and occasional liverworts between these patches." (Lee, 1951, 1-2). ". . . *Succinea vaginacontorta* Lee is xerophilous. Its usual habitat is a treeless slope of a hillside supporting a ground cover of short grass, sagebrush, and lichens. This species appears on the surface in the summertime after rains have soaked the ground. During periods of drought it disappears and may not be seen again for months or even years." (Franzen, 1971, 132). Average annual precipitation of Meade County, Kansas, is 18.72". (Yearbook of Agri., 1941, 874).

Succinea vaginacontorta is known from localities of the high plains including Meade County, Kansas; Brown County, Nebraska; Washabaugh County, South Dakota; San Miguel County, New Mexico (Franzen, 1971) and later from other counties of SW Kansas; Yuma County, Colorado; Sherman County, Texas; and Platte County, Wyoming.

Succinea indiana Pilsbry was collected by L. E. Daniels in 1904 from ". . . just south of New Harmony, Posey Co., Indiana, on the hillside facing west between the marl cliffs and the highway." (Pilsbry, 1948, 817). I have visited the site a number of times and have observed changes. The hillside supports a growth of timber consisting of hardwoods up to its western slope. The west end of the hillside has been altered since the time Daniels collected the succineas. The slope facing the highway has been excavated. For a number of years the western end of the hill was burned annually which controlled the growth of the brush. In recent (about six or seven) years the area has not been burned; the brush has become dense and impenetrable. The average annual precipitation of Posey County, Indiana, is 42.34". (Yearbook of Agri. 1941, 855). The habitat of this site does not resemble that of the high plains where *S. vaginacontorta* is known to live.

The geographic distribution, habitat, and shell characters distinguish *Succinea vaginacontorta* Lee from *Succinea indiana* Pilsbry. *S. vaginacontorta* is, therefore, not a synonym of *S. indiana* but a valid species.

Acknowledgments

National Science Foundation Grants-in-Aid No's. NSF G18000 and NSF GB2715 provided laboratory equipment and supported, in part, field studies. I am grateful to Dr. A. Byron Leonard for reviewing the manuscript. The Academy of Natural Sciences of Philadelphia graciously loaned me type specimens of *Succinea indiana* Pilsbry.

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A NEW SPECIES OF *CORALLIOPHILA* (GASTROPODA: CORALLIOPHILIDAE) FROM SOUTHEASTERN POLYNESIA

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ABSTRACT

Coralliophila latilirata *is described as new from southeastern Polynesia and compared with* C. bulbiformis *Conrad (1837).*

The receipt from M. Jean Trondle of La Force, France, of numerous specimens of a species of *Coralliophila* from the shores of Anaa Atoll in the Tuamotus, called my attention forcefully to the distinctness of a species which I had collected earlier in French Polynesia, Pitcairn, and Cook Islands, but only in single lots or as fragments. A careful comparison of material of this species with that of *C. bulbiformis* Conrad (1837) has revealed not only its distinctness, but also that it is found only in a rather limited area.

Coralliophila latilirata, *new species*

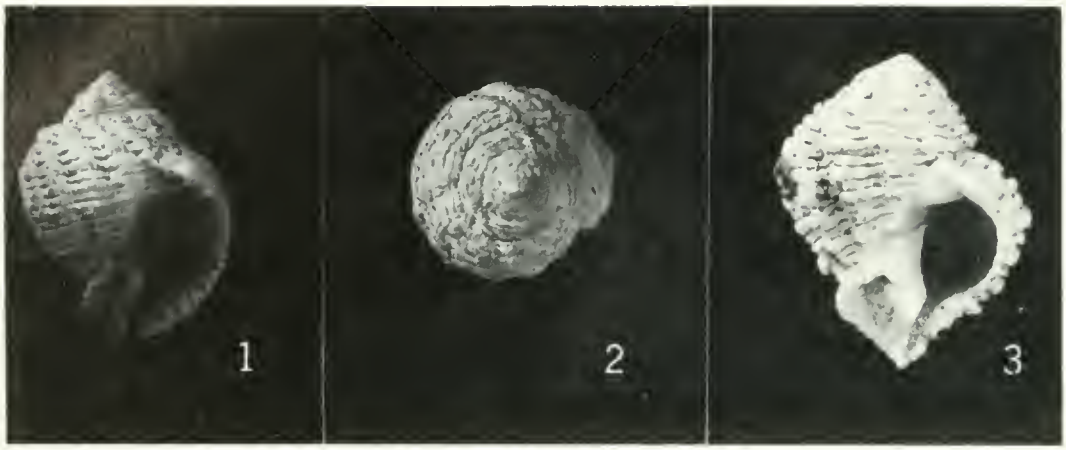
Figs. 1-3

Diagnosis: Shell of moderate size, 15-30.75 mm in length, globose to broadly ovate, with numerous crowded, broad, scabrous, flattened spiral cords; aperture deep lavender to pale purple, occasionally white. It is close to *bulbiformis* Conrad, (1837) but is more inflated, with a lower spire, and broad, crowded, flattened, spiral cords.

Range: Southern Cooks, western Austral Islands, Society Islands, Tuamotus, and Pitcairn Group (Fig. 4).

Description: Shell stout, thick-shelled, globose to broadly ovate, white, adults from 15 to 30.75 mm in height, width from 70% to 92% of height. Protoconch polygyrate, conical, pinkish, about 4¾ whorls; first whorl apparently smooth (partially-broken off), following whorls with a nodulose spiral keel below a sloping shoulder with axial riblets which are somewhat prosocline to opisthocyrt[1]; a second keel gradually forms above the main keel resulting in the last 1 1/5 protoconch whorls bearing two keels made nodulose by the axial riblets. Postnuclear whorls about 6 (earliest whorls generally worn or covered with calcareous deposit), early ones

[1]"somewhat inclined forward to curved backwards" – Editor.



FIGS. 1-3. *Coralliophila latilirata* n. sp. **1** and **2** apertural and top views of the holotype, USNM 731531, height 25.22 m. **3**, apertural view of paratype, USNM 845460, height 30.78 mm.

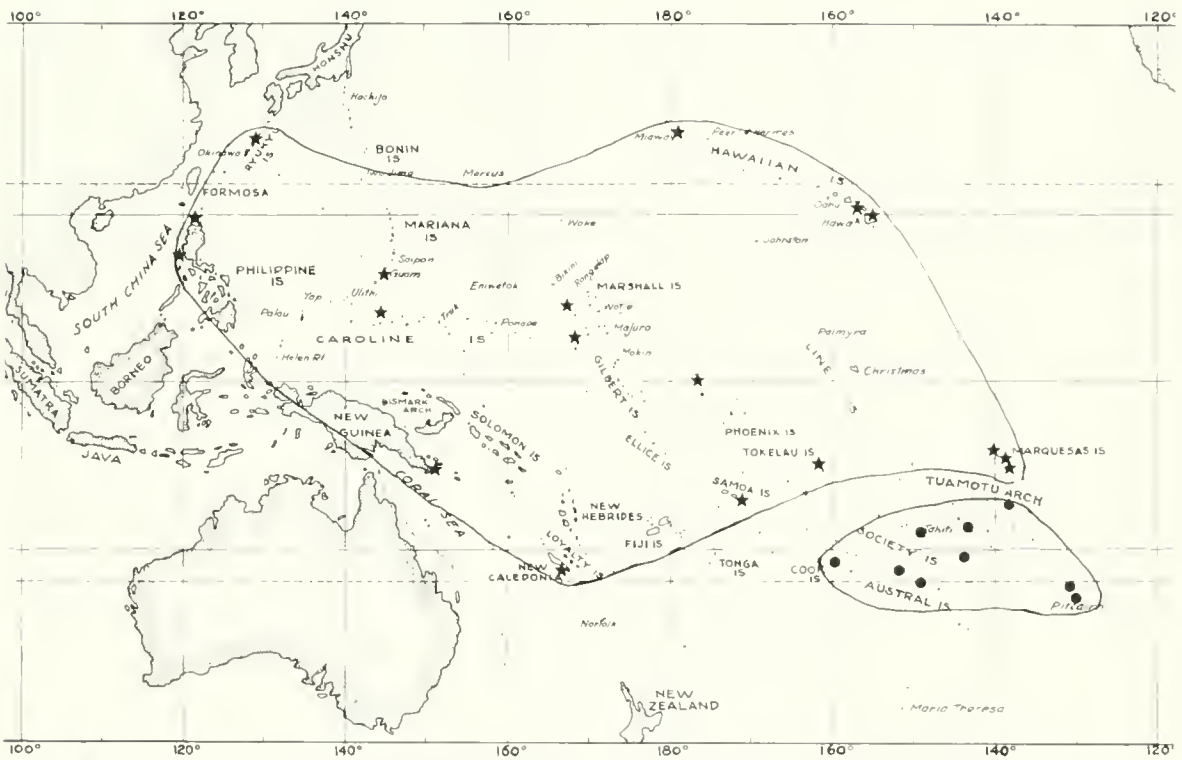


FIG. 4. Map showing distribution of *Coralliophila latilirata* n. sp. (circles), and *Coralliophila bulbiformis* Conrad (stars).

strongly carinate, with four broad lirae, finely scalloped, separated by narrow grooves and crossed by broad rounded axial ridges, rendering the surface of the whorls wavy; in later whorls the axial ridges become broader and lower, and the spiral ridges more irregularly nodose, or flattened, the separating grooves usually very narrow; the penultimate whorl generally with five spiral ridges; body whorl evenly convex, with about 17 irregularly flattened ribs that are axially and densely lamellate; the lamellae generally fused together especially on the prosocyrt axial ridges that number thirteen on the body whorl of the holotype, but may be fewer and broader on other specimens; in worn specimens the axial lamellae that compose

the broad spiral lirae may be more or less obscure due to fusion and some erosion. Aperture oval, ending anteriorly in a short to moderately long, curved, narrowly attenuated canal; outer lip made finely crenulate by the ends of the external spiral ridges; columella and interior of aperture deep-to pale-lavender, (light grayish purplish red to grayish purplish red: Kelly & Judd, 1965); a strong lamellose fasciole, surrounding a broad to moderately narrow false umbilicus, terminates in the end of the siphonal canal.

Habitat: Host unknown. Found alive under and near coral in 40-55 ft. and dredged in 50-56 fathoms. Found in stomachs of fish (*Coris aygula*) caught in 50-100 ft.

Type Locality: Oeno, Pitcairn Islands.

Material: Holotype: lagoon, northshore, in 1-6 ft. on hard pan bottom, Oeno, Pitcairn Islands, collected by H. A. Rehder, 18 December 1970 (USNM 731531). Paratypes–COOK ISLANDS: W. of Avatiu, Rarotonga in 45 m (USNM 732270); E of Avarua, Rarotonga, in 25 m (USNM 732262); AUSTRAL ISLANDS: NW of Moerai, Rurutu, in 40-50 m (USNM 732217); north coast, Tubuai, 25 m (USNM 732294); SOCIETY ISLANDS: E side Taunoa Pass, Arue, Tahiti (USNM 668779); TUAMOTUS: NW side Puka Puka (USNM 789879); NW end of lagoon, Anuanuraro (USNM 725347); dead on beach, Anaa (USNM 845460; Colln. Trondle); dead on beach, Raroia (USNM 697956, 697685, 698743). PITCAIRN ISLANDS: off NW corner, in 100-124 m Pitcairn (USNM 789442); off Bounty Bay in 15-16.7 m Pitcairn (USNM 731663); W of Bounty Bay, in 30 m (USNM 731831); off Christian's Point, in 15 m (USNM 731765).

The two lots from the Cook Islands, the lot from Rurutu, and two of the lots from Pitcairn (USNM 731831, USNM 731765) all consist of fragments found in the gut of specimens of the fish, *Coris aygula*, speared at the depths indicated.

Measurements (mm):

	height	width
USNM 731531 holotype	25.22	20.18
Trondle Colln. paratype	30.75	25.05
USNM 731663 paratype	21.83	20.26
Trondle Colln. paratype	19.18	16.85
Trondle 789453 paratype	18.08	14.64
Trondle 725347 paratype	16.32	14.34
USNM 789879 paratype	15.05	13.05

Twenty-five specimens were measured and found to range between 30.75 to 15.05 mm in height and 25.05 to 13.05 mm in width; the average height is 21.72 mm and the average width is 18.14 mm.

Etymology: From the Latin, meaning "with broad ridges."

Discussion: This species is closest to *Coralliophila bulbiformis* Conrad, 1837, but is less elevated, with a low broad spire with flattened whorls, the spiral lirae less numerous, broader, flattened, and made nodulose by more or less worn lamellae, and the axial ribs lower, less prominent than in most specimens of *bulbiformis*.

Good illustrations of *C. bulbiformis* Conrad may be found in Cernohorsky 1978 (pl. 21, fig. 4) and Kira, 1962 (p. 68, pl. 26, fig. 6). *C. bulbiformis* is identified as *C. costularis* Lamarck, 1816, by Salvat and Rives, 1975 (p. 310, fig. 190), but the latter is a narrower, fusiform species that is found from East Africa to the Ryukyus. Similarly, *C. bulbiformis* is synonymized by Kay in her Hawaiian Marine Shells (Kay, 1979, p. 255, pl. 90B) under *C. erosa* (Röding), but an examination of the description and figures in Chemnitz on which Röding based his name shows that *erosa* is the species that Kay describes and figures (Kay, 1979, p. 255, fig. 90A) under *C. dorbignyana* (Petit, 1851), a junior synonym of *erosa*.

Coralliophila bulbiformis Conrad varies considerably in shape, from rather elevated with strongly convex, more or less angled whorls with consequently indented sutures to ovate species with only slightly convex whorls and less indented whorls. The latter form is common in the Hawaiian Islands, while the Marquesan specimens are more elevated with convex whorls, as are most of those in the rest of the range of the species. It is a distinct species, and not a subspecies of *C. erosa*, as Abbott and Dance (1982, p. 155) cite it.

This new species is restricted, as far as we now know, to the Cook Islands and French Polynesia, including the Pitcairn Islands (Fig. 4). It has however not been found in the Marquesas, where *C. bulbiformis* occurs, or in Rapa. *C. bulbiformis* is found from the Ryukyus and Philippines eastward to Hawaii, the Marquesas Islands, Samoa and New Caledonia.

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NATIVE FRESHWATER MUSSELS (UNIONACEA) AS FOULING AGENTS IN ELECTRICAL GENERATING PLANTS

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ABSTRACT

The occurrence of native freshwater mussels (Unionacea) as fouling agents in the water supply system of an electrical-generating plant is reported. Details of the reported problem and discussion of the likelihood of similar occurrences in additional generating plants are presented.

While the Asiatic clam, *Corbicula fluminea*, is well-known as a fouling agent in electrical generating plants (Mattice, 1977; Smithson, 1981), native unionids have not been implicated in similar situations. Absence of unionids in water distribution systems has been attributed to lack of byssus attachment (see Ingram 1953). Herein I record an example of both *Corbicula* and native unionids as fouling agents in a cooling water supply main for a lignite-fired electrical generating plant. The purposes of this study were (1) to understand factors significant in this fouling example and (2) to determine if this was an isolated incident or a forerunner of future problems at other power plants.

Alcoa Lake is a 5972-hectare reservoir located 11 km southwest of Rockdale, Milam Co., Texas. The impoundment was created in 1953 on Sandy Creek, a tributary of East Yegua Creek in the Brazos River drainage. The limited surface runoff water is supplemented by an aqueduct which transports water approximately 20.5 kilometers from the Little River, also in the Brazos drainage. The unionids reported below probably originated from the Little River, although some stocking of fish has occurred in Alcoa Lake.

Jule Frankeny of International Generating Corporation, operator of the Sandow Power Plant at Alcoa Lake, informed me that a number of clams had been forced under pressure in August 1983 from a service line (off the supply main) which had been partially blocked. Inspection of recovered clams revealed *Anodonta grandis, Cyrtonaias berlandieri* and *Corbicula fluminea;* all three species have been reported from the Brazos drainage (Strecker 1931; Fontanier 1982). These clams were recovered from a 14-inch diameter pipe located four feet below ground surface. To reach this pipe, the individuals recovered had passed through an initial traveling screen (12.8 mm mesh), large pump, booster pump (19.5 mm bore), and another strainer (4.8 mm mesh).

Two water supply mains transport water from Alcoa Lake to the Sandow plants. Both mains are of equal size (initially 78" diameter), but one main supplies two plants while the second only supplies one plant (a planned fourth plant was

never built). Unionids were found only in a service line off the second main where decreased water velocities apparently allowed sediment and clams to accumulate to a degree that water flow was eventually restricted.

A typical recovered *A. grandis* shell was 127 mm in length and 72.2 mm in height. This "long, low" phenotype corresponds to the nominate variety. The shell is highly polished, especially on the older part of the shell. Dark rings may represent annual growth rings which are generally faint to absent on most Texas shells. Ring production could be due to differences in growth rate due to variations in water temperature and/or food supply. Total number of rings is ten.

Cyrtonaias berlandieri from this supply main were small and rather thick-shelled but appeared similar to examples from surface water populations from central Texas. Nacre color was light pinkish purple; typical shell height and length was 73.0 mm and 51.0 mm, respectively.

Corbicula fluminea shells were small with the largest measuring 28.45 mm in length; all shells were of the "white morph."

The only similar example recorded in the literature was by Button (1900). Two examples of *Margaritifera margaritifera* var. *falcata* which were collected in a water tunnel near Santa Cruz, California. The shells were found 700 feet from the mouth of the tunnel at a depth of 300 feet. Button (1900) did not state that the examples were alive, but he described the shells as "unusually large and thin, the nacre being richly colored."

Occurrence of unionids in water lines of an electrical generating plant raises questions concerning the likelihood of these clams becoming major problems in such plants. The existence of this problem at the Sandow complex could be significant because these plants were the first lignite-fueled electric generating units in Texas (Espey, Huston and Associates 1983: 60). Sandow #1 and #2 went on line in 1953 with Sandow #3 becoming operational in 1954. Existence of clams only in the line servicing #3 indicates that the occurrence of unionids as a fouling agent in electric generating plants probably will be a minor problem. The passage of young unionids through the screening mechanisms is likely to be a low probability event, especially in contrast to passage of minute larval forms of *Corbicula fluminea*. Survival of young unionids which do pass through these screens is unlikely except in those pipes with low velocity flows which do not exceed appropriate entrainment velocities.

I thank Jule Frankeny and Pete Goggin for supplying the clams and information on the power plants.

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ILLUSTRATED CATALOGUE OF LATIAXIS AND ITS RELATED GROUPS FAMILY CORALLIOPHILIDAE

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TERAMACHIA DUPREYAE NEW SPECIES, FROM OFF WESTERN AUSTRALIA (GASTROPODA: VOLUTIDAE)

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ABSTRACT

Teramachia dupreyae, *a new species from deep water 200 miles NW of Broome, Australia, is described and compared with related species of the volutid subfamily Calliotectinae. In addition to this newly described taxon, the following species are recognized in the genus* Teramachia: tibiaeformis *Kuroda, 1931,* dalli *(Bartsch, 1942),* smithi *(Bartsch, 1942),* johnsoni *(Bartsch, 1942),* mirabilis *(Clench and Aguayo, 1941), and* shinzatoensis *MacNeil, 1961.*

Through the kind offices of Robert and Dorothy Janowsky, proprietors of *Mal de Mer Enterprises* of West Hempstead, New York, the presence of recently obtained specimens of this interesting discovery were brought to my attention. I am pleased to describe this new western Australian volute in honor of Constance Duprey of Nashville, Tennessee, who generously submitted her specimens for study and donated the holotype to the American Museum of Natural History (AMNH).

A total of seven species, including the new taxon described herein, are recognized in the genus *Teramachia* at the present time. Five living and one extinct species are known from the western Pacific. A single extant species is reported from the western Atlantic.

The previously known species-group taxa referable to *Teramachia* are listed in sequence of publication:

1. *Teramachia tibiaeformis* Kuroda, 1931, pp. 45-47, figs. 2, 3; Kuroda and Habe, 1950, pp. 36, 37, pl. 5, fig. 1, text fig. 5 (operculum), "Tosa in 100 fms." [182 meters]; Habe, 1952, p. 132, fig. 12 (radula); Azuma, 1960, p. 48, pl. 2, fig. 9, off Tosa, in 182 meters; Kira, 1962, p. 92, pl. 33, fig. 4 (illus. in color), "Honshû and southwards, rarely found at 100-150 fathoms depth" [182-274 meters]; Shikama, 1963, p. 97, pl. 79 (illus. in color), Hyuga, Japan; Weaver and duPont, 1970, p. 179, pl. 76 E, F (illus. in color), text fig. 41b (operculum); Abbott and Dance, 1982, p. 224 (illus. in color). Type locality: "Off Kii", [Honshû, Japan]. The type species of *Teramachia* Kuroda, 1931. This well-known, small species (length to 90 mm) seems to be restricted to southern Japanese waters. The holotype is in The Academy of Natural Sciences of Philadelphia.

2. *Teramachia mirabilis* (Clench and Aguayo, 1941), pp. 177, 178, pl. 14, fig. 2; Clench and Turner, 1964, p. 177, pl. 114 (holotype); Weaver and duPont, 1970, p. 178, pl. 76 A, B (holotype, illus. in color). Type locality: "off Matanzas, Matanzas Prov., Cuba,...in 289 fathoms [528 meters]". The type species of *Howellia* Clench and Aguayo, 1941.

3. *Teramachia dalli* (Bartsch, 1942), pp. 10, 11, pl. 2, figs. 1 (operculum), 4; Weaver and duPont, 1970, p. 177, pl. 75 E, F (holotype, illus. in color), text fig. 41a (operculum); Lan, 1980, p. 63, pl. 25, figs. 55, 55a, "SW off Taiwan"; Bouchet, 1981, p. 10, illus., NW of Mindoro, Philippines, in 680-770 m; Abbott and Dance, 1982, p. 224 (holotype, illus. in color); Okutani, 1983, p. 10, pl. 33, fig. 5, "Taiwan"; Wells, 1983, p. 5, illus., off Port Hedland, northwest Australia, in 376 meters. Type locality: "off Cape Santiago, Luzon, [Philippines], in 394 fathoms [720 meters]." The type species of *Prodallia* Bartsch, 1942. This stout but thin shelled species attains 175 mm in length. The prominent suture is deeply grooved and off-set by regular and evenly spaced ribs, which are terminally cuspate at the summit. The periostracum on fresh specimens is a blackish brown.

4. *Teramachia smithi* (Bartsch, 1942), p. 11,

pl. 2, fig. 5; Weaver and duPont, 1970, pp. 178, 179, pl. 76 C, D (holotype, illus. in color); Greene, 1975, p. 12, illus., "10 miles southeast Taghilaran, Bohol, Philippines, trawled alive"; Clover, 1978, pp. 60, 61 (illus. in color), "Off Boho, Philippines, in 200 meters"; Abbott and Dance, 1982, p. 224 (holotype, illus. in color). Type locality: "off Balicasag Island, Bohol [Philippines], in 439 fathoms [802 meters]". This large shell (length 173.5 mm, Duprey coll. A429) is characterized by the narrow spire, inflated body whorl, with a wide aperture and a widely flaring outer lip. The periostracum is a tannish brown.

5. *Teramachia johnsoni* (Bartsch, 1942), p. 12, pl. 2, fig. 3; Weaver and duPont, 1970, p. 178, pl. 75 G, H (holotype, illus. in color); Rehder, 1972, p. 8, figs. 3, 7; Lan, 1980, p. 63, pl. 25, figs. 54, 54a, "SW off Taiwan" (not *T. tibiaeformis*); Okutani, 1983, p. 10, pl. 33, fig. 4, "Cebu, Philippines" (not *T. tibiaeformis*), fig. 6, "South China Sea" (not *T. smithi*) and fig. 7, "Taiwan". Type locality: "3½ miles NW of Cagayan Island, [Philippines], in the northern Sulu Sea, in 344 fathoms [628 meters]," *fide* Rehder, 1972, p. 8. Originally described on the basis of an immature specimen, Rehder (1972, pp. 8, 9, figs. 3, 7) subsequently described an adult specimen of this narrowly and elongately fusiform species, which is known to attain 145 mm in length. The light brown periostracum covers a grayish to tannish shell with the suture stained a darker gray. The outer lip is strongly arcuate. Populations from the Formosa Strait were afforded subspecific recognition by Rehder; see *T. j. williamsorum, infra citato.*

6. *Teramachia shinzatoensis* MacNeil, 1961, p. 96, pl. 9, fig. 1; Rehder, 1972, p. 8, figs. 5, 6 (holotype). Type locality: "Shinzato tuff member, [Neogene, Okinawa, Japan]". This small (length 69.8 mm), Mio-Pliocene fossil is compared with *T. johnsoni* by MacNeil (1961, *op. cit.*) and Rehder (1972, *op. cit.*).

7. *Teramachia johnsoni williamsorum* Rehder, 1972, pp. 8, 9, figs. 1, 2, 4; Abbott and Dance, 1982, p. 224 (holotype, illus. in color). Type locality: "30 miles south of Tung-Chiang, Taiwan, in 150 fathoms [274 meters]". All the specimens I have examined of this form are from the Formosa Strait. Abbott and Dance (*op. cit.*) consider this taxon to be an infrasubspecific form of *T. johnsoni* Bartsch. The available data suggest that Rehder's taxon is conspecific with *T. johnsoni.* As in the new species, shell dimorphism is expressed by a stout form (Rehder, 1972, figs. 1, 4, holotype of *T. j. williamsorum*) and a slender form (Rehder, 1972, figs. 3, 7).

Family Volutidae Fleming, 1822
Subfamily Calliotectinae
Pilsbry and Olsson, 1954
Genus ***Teramachia*** Kuroda, 1931

Teramachia Kuroda, 1931, p. 45, type species by monotypy, *Teramachia tibiaeformis* Kuroda, 1931, pp. 45-47, figs. 2, 3, off Kii, Japan.

Howellia Clench and Aguayo, 1941, p. 177, with its type species by monotypy, *Howellia mirabilis* Clench and Aguayo, 1941, pp. 177, 178, pl. 14, fig. 2, off Cuba, in 285 fathoms [520 meters], was based solely on the holotype, without knowledge of the soft parts and operculum, and was provisionally placed in the Fasciolariidae. Clench and Turner (1964, p. 178, pl. 114) subsequently assigned *Howellia* to the Volutidae, subfamily Calliotectinae, following Pilsbry and Olsson (1954, p. 19). Clench and Turner (*op. cit.*) noted the close resemblance in shell morphology of the type species to the genus *Teramachia.* The western Atlantic *T. mirabilis* does recall examples of *T. tibiaeformis* from Japan, but differs in having the strong axial sculpture carried on to the body whorl. A more precise systematic assessment of *Howellia* must await knowledge of the soft parts and the radular characters of the type species.

Prodallia Bartsch, 1942, p. 10, with its type species by original designation, *Prodallia dalli* Bartsch, 1942, p. 10, off Luzon, Philippines, *ex*-Bartsch ms., was introduced in a 20-page brochure circulated at a banquet in honor of William Healey Dall, on April 21, 1915. Because the banquet brochure was not available to the general public, these taxa were not nomenclaturally available until 1942 when Bartsch first validly proposed the names.

Kuroda (1931, p. 47) provisionally placed the genus *Teramachia* in the Volutidae largely on the basis of shell and opercular morphology. This familial assignment was retained by Kuroda and Habe (1950, p. 36). Subsequently, Habe (1952, p. 132, fig. 12) figured the rachidian teeth of *T. tibiaeformis*, without comment.

Pilsbry and Olsson (1954, p. 19) included *Teramachia* (with *Prodallia* in synonymy) in their volutid subfamily Calliotectinae. They illustrated a tricuspid rachidian tooth (Pilsbry and Olsson, 1954, pl. 3, fig. 16) of the type species of *Calliotectum* Dall, 1890, which has rachidian dentition similar to that illustrated by Habe (1952, *op. cit.*) for *T. tibiaeformis*. The radular and opercular characters of *Teramachia tibiaeformis* strongly indicate placement of this genus in the Volutidae (Weaver and duPont, 1970, p. 176; Rehder, 1972, p. 7; Cernohorsky, 1973, p. 127; Emerson and Old, 1979, p. 11; Quinn, 1981, p. 73), although some authors have assigned *Teramachia* to the Turbinellidae (*olim* Xancidae) largely on the basis of shell morphology (Bayer, 1971, p. 195; Abbott and Dance, 1982, p. 224).

Rehder (1972, p. 7) reported the presence of two oblique folds on the columella of immature specimens of *T. tibiaeformis* and *T. johnsoni*, which become obscure in the adult stage. These folds are weakly developed. None of the specimens I have examined of the species herein referred to *Teramachia* possesses columellar plications. Taxa with columellar plaits, which were previously assigned to the calliotectine volutes, are now placed in the Turbinellidae (Rehder, 1967, 1972; Cernohorsky, 1973; and Quinn, 1981). This includes *Prodallia barthelowi* Bartsch (1942, pp. 12, 13, fig. 2) from the Philippines.

The new species of *Teramachia* is one of many new or otherwise interesting deep-water species recently obtained by shrimp boats trawling off the northwest coast of Australia; see Davis and Ward (1984). Kosuge (1985) lists and illustrates some of these findings in a preliminary report on the mollusks.

Teramachia dupreyae *new species*

Figs. 1-8

Teramachia aff. *T. dalli* (Bartsh [*sic*], 1942), Slack-Smith, 1980, p. 1, illus., "SW of Cape Leeuwin, W. Australia, in 488-496 m." Not *Teramachia dalli* (Bartsch, 1942).

Teramachia johnsoni (Bartsch, 1942), Kosuge, 1985, p. 58, pl. 23, fig. 1, off the northwestern coast of Australia. Not *Teramachia johnsoni* (Bartsch, 1942).

Diagnosis: Shell large for genus, exterior a tannish white, aperture a glossy white, suture and anterior portion of columellar wall stained a brownish lavender; periostracum inconspicuous, thin, yellowish buff. The darkly colored sutural line against the light color of the shell immediately distinguishes this elegant volute from its congeners.

Description: Shell large, attaining 195+ mm in length, slenderly elongate fusiform. Protoconch missing; remaining whorls of holotype 10½. Lined suture narrow, canaliculate on early whorls, with axial ribs, numbering 33 to 37 on last completely ribbed whorl; ribs obsolete on lower portion of antepenultimate whorl and wanting on the penultimate and body whorls, on which irregular growth lines occur. Aperture elongate, outer lip flaring, edge thin; anal sulcus with narrow sinus at juncture with suture; anterior siphonal canal widely open; parietal lip thinly glazed; columella without plications, and weakly folded. Operculum typical for the genus (Kuroda and Habe, 1950, p. 46, fig. 5). Soft parts not preserved. Color, see Diagnosis above.

Shell dimorphism is characterized by slender individuals (holotype, here illustrated, figs. 7, 8 and paratypes C and D) and a shorter, inflated form (paratype A, here illustrated, figs. 3, 4).

Measurements: Holotype, 185 mm in height, 46 mm in width; paratype A, 145 mm in height, 48.5 mm in width; paratype B, 153 mm in height, 44 mm in width; paratype C, 192 mm in height, 48.7 mm in width; paratype D, 197 mm in height, 42.5 mm in width; paratype E, 184.2 mm in height, 42.8 mm in width; and paratype F, 166 mm in length, 39.9 mm in width.

Type locality: 200 miles NW of Broome, Australia off McDonnell Reef in 400 meters, February 1985. Type specimens: holotype, AMNH 213477 (figs. 7, 8); paratypes A (figs. 3, 4, 6) and B (figs. 1, 2, 5) and C from type locality, Constance Duprey collection; paratype D, AMNH 213438, here transferred to the Western Australian Museum, Perth, from 200 miles NW of Broome, between Rowley Shoals and Scotts Reef, in 450 meters; paratype E, AMNH 214367, off Broome, in 184 meters; and paratype F, AMNH 214368, off Port Hedland, NW Australia, in 166 meters.

Remarks: Of the nominal species of *Teramachia*, the present species most closely resem-

FIGS. 1-8. *Teramachia dupreyae* new species. **1, 2,** Paratype B. **3, 4,** Paratype A. **5, 6,** enlarged early whorls, **5,** Paratype B; **6,** Paratype A. **7, 8,** Holotype, AMNH 213477. **1-4, 7, 8** approximately × ⅔; **5, 6** approximately × 1.5.

1

2

3

4

5

7

8

bles in general appearance *T. johnsoni*, which differs in having the body whorl and penultimate whorl purplish gray, the early whorls yellowish white or white, and the outer lip a grayish purple with a brownish margin inside the whitish edge of the lip (Rehder, 1972, p. 9). In *T. tibiaeformis*, a dark spiral band appears below the suture on the body whorl and penultimate whorl of some specimens (cf. Abbott and Dance, 1982, illus. on p. 224). In *T. dupreyae* new species, the spiral coloration is restricted to a thin brownish lavender line within the suture (see figures herein).

Specimens of the new species from the continental slope off northwest Australia were previously recorded and illustrated by Slack-Smith (1980, p. 1), who compared her specimen with *Teramachia dalli* (Bartsch), and by Kosuge (1985, pl. 23, fig. 1), who referred his to *T. johnsoni* (Bartsch). *Teramachia dalli* is also reported from off the northwest coast of Australia in moderate depths (Wells, 1983, p. 5, illus.); Kosuge, 1985, p. 59, pl. 23, fig. 6). An additional specimen of *T. dalli* was trawled, in March 1985, off McDonnell Reef, 200 miles NW of Broome, Australia and was examined by me courtesy of Constance Duprey. This dark-colored species differs from the present species in the presence of stronger, axial ribs, which extend to upper part of the body whorl, and in the development of a deeply and broadly channeled suture.

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ADDITIONAL COLORADO RECORDS OF *ANODONTA GRANDIS GRANDIS* SAY (BIVALVIA: UNIONIDAE)

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Upon first finding *Anodonta grandis grandis* Say, 1829, in large numbers in the Colorado Fuel and Iron Reservoirs No. 2 and No. 3 near Pueblo, Colorado, in August of 1982, we became concerned about the rarity of them elsewhere in the state. Since the summer of 1982 we have been searching eastern Colorado for viable populations of this freshwater mussel.

All the water in C.F.&I. Reservoir No. 3 had to be released by February 1983 so a new water control valve could be installed in the dam before the spring runoff began. As the water level was lowered, thousands of *Anodonta grandis grandis* became exposed. In February 1983 we transferred 412 adults from the C.F.&I. Reservoir No. 3 to the newly formed Pueblo Reservoir. Statewide news media coverage of this transplanting operation brought many calls and messages regarding the occurrence of bivalves elsewhere in eastern Colorado. Each of these notices was investigated. If during these investigations *A. grandis grandis* was found, we attempted to collect the largest (in length) and smallest specimens available. In addition, from each site at which *A. grandis grandis* was found a 1 liter composite (surface to near bottom) water sample was collected and kept on ice in a cooler until our return to the laboratory. In the Water Resources Laboratory of the University of Southern Colorado standard methods were used to analyze the cooled water samples. Atomic absorption spectrophotometric methods were used for the analysis of Na, K, Cu, Mn, Fe, and Zn. Sediment was examined in the field for relative particle size.

Burch (1973) indicated the North American range for *Anodonta grandis grandis* as being throughout the Mississippi-Missouri River drainage. In Colorado Brandauer and Wu (1979) cite only two old records for this species: one from 1911 in Boulder County, 30 miles north of Denver, consisting of 1 specimen; and a second collected 10 October 1915 from Yuma County, a pool in Black Wolf Creek, 1½ miles north and 1 mile west of Beecher Island, consisting of 35 specimens. The large collection from Black Wolf Creek in far eastern Colorado was made by Ellis (1916), who reported they were abundant and tightly embedded in the dense blue clay bottom. On 21 October 1983 we visited the vicinity of Black Wolf Creek described by Ellis (1916) and Brandauer and Wu (1978) and attempted to collect living specimens. All we found after searching about a mile segment were four shell frag-

ments of this species. Without more specific information it was impossible to locate the Boulder County site. It is quite possible that *Anodonta grandis grandis* is now extinct in the two sites reported by Brandauer and Wu (1978).

Recently, Wu (1984) reported to us another locality where this species is surviving. The 30 specimens and one valve (University of Colorado Museum [UCM] Collection No. 28913) erroneously identified as *Anodontoides ferussacianus* (Lea) in Brandauer and Wu (1978) p. 48, from Boyd Lake, Larimer County are in fact *Anodonta grandis grandis*. An additional collection (UCM No. 32168) from Boyd Lake of two specimens and six valves are also *A. grandis grandis*.

Four lentic sites were found to support thriving populations. Two of these sites, C.F.&I. Reservoir No. 2 and No. 3, are new drainage records for Colorado. To date *Anodonta grandis grandis* has not been reported from the Arkansas River drainage in Colorado. These two records probably represent the extreme westward extension of the range of this species because only ten miles (16 km) west the Great Plains give way to the foothills of the Wet Mountain frontal range. The other two sites, Mayham Lake and Flagler Reservoir, are located in the South Platte and Republican River drainages respectively. The specific geographical and altitudinal data for each of these four sites are indicated in Table 1. All are on the Colorado Great Plains and occur at about the same elevation. If in the past a site had a different name, or is today known by multiple names, all such names have been indicated in Table 1.

The range in size (total length) for all living naiads examined from each site were as follows: Flagler Reservoir (85 to 186 mm for 42 specimens), Mayham Lake (30 to 160 mm for 80 specimens), C.F.&I. Reservoir No. 2 (19 to 183 mm for 121 specimens), and C.F.&I. Reservoir No. 3 (11 to 192 mm for 534 specimens). We have determined that in the latter two sites this species showed a continuous age structure from one to fifteen years. It appears to us that *Anodonta grandis grandis* is reproducing and thriving in all four sites.

A comparison of the water quality for the four study sites in Table 2 shows all have hard water (171 to 233 mg/L $CaCO_3$) that is highly buffered. Trace metals (Fe, Cu, Zn, and Mn) in the dissolved fraction are all relatively low (<0.2 mg/L) and do not appear to present any toxic problems. Under these conditions *Anodonta grandis grandis* could be expected to have available sufficient calcium carbonate for shell construction. In addition, all the sediments contained varying mixtures of particles from clay to coarse sand. The occurrence of this species in a wide variety

TABLE 1. Geographical and altitudinal data for new site records of *Anodonta grandis grandis* Say in Colorado.

Name of reservoir	Elevation ft. a.s.l.* (m a.s.l.)	County	Coordinates	Locality	River drainage
Flagler Res.	4707 (1435)	Kit Carson	T9S, R50W, S5, 4, 9, 10	34 mi (57 km) E. of Limon	Republican
Mayham Lake (Hidden Lake or Mud Lake)	5281 (1610)	Adams	T3S, R68W, S6	1 mi (1.6 km) S. of Westminster (N.W. Denver)	South Platte
C.F.&I. Res. No. 2 (St. Charles Res. No. 2)	4913 (1497)	Pueblo	T21S, R65W, S34 & 35	9 mi (14.5 km) S. of Pueblo	Arkansas
C.F.&I. Res. No. 3 (St. Charles Res. No. 3)	4960 (1512)	Pueblo	T21S, R65W, S33 & 34 and T22, R65W, S3 & 4	9 mi (14.5 km) S. of Pueblo	Arkansas

*feet above sea level (meters above sea level)

TABLE 2. Physico-chemical water quality data for four new site records of *Anodonta grandis grandis* Say in Colorado. All data reported as mg/L except dates, turbidity, pH, and conductivity. *is raw water determination. **not detectible (<0.01 mg/L).

Parameter	Flager Res.	Mayham Lk.	C.F.&I. Res. No. 2	C.F.&I. Res. No. 3
Date of water sampling	21 Oct. 83	6 Sept. 83	14 Feb. 84	3 Mar. 84
Turbidity* (JTU)	38	40	15	10
Total Hdns. ($CaCO_3$)	232	171	233	179
Ca Hdns. ($CaCO_3$)	120	105	182	121
Mg. Hdns. ($CaCO_3$)	112	66	51	58
Cl	72.5	81.0	11.5	23.5
SO_4	45	41	35	28
Na	102	117	19	16
K	13.6	18.0	3.0	2.8
Conductivity (μS)	870	890	480	370
Fe	ND**	ND	ND	ND
Cu	.005	.005	.003	.003
Zn	.012	.006	.014	.014
Mn	.005	.160	.006	.006
T-alk* ($CaCO_3$)	141	118	138	131
pH*	8.2	8.3	7.3	7.6

of substrates was documented by Clarke and Berg (1959).

All four reservoirs support a variety of common warm-water fish: the green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), and carp (*Cyprinus carpio*). In addition, Flagler Reservoir supports a thriving population of largemouth bass (*Micropterus salmoides*), and C.F.&I. Res. Nos. 2 and 3 channel catfish (*Ictalurus punctatus*), white crappie (*Pomoxis annularis*), and black crappie (*Pomoxis nigromaculatus*). Most of these fish are known hosts for the glochidia of *Anodonta grandis grandis*.

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A 40-WEEK STUDY ON GROWTH OF THE ASIAN CLAM, *CORBICULA FLUMINEA* (MÜLLER), IN THE KANAWHA RIVER, WEST VIRGINIA

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ABSTRACT

A sample population of Corbicula fluminea *individuals maintained in cages was monitored over a 40-week period (12 March to 16 December 1983) to assess growth (in shell length, and overall body weight), percentage of total body weight made up of soft tissues (i.e. "condition index"), and mortality rate. There were virtually no increases in length or weight when water temperatures were below 10°C. Noticeable growth began when water temperature reached ~ 14°C. Highest rates of growth (shell length, 0.66 mm/wk; weight, 0.26 gm/wk) occurred when water temperatures were between 24° and 30°C. "Condition indices" (ranging from a low of 12.6% in June to a high of 21.2% in October) for experimentally caged clams were similar to those found in natural stream clams. Twenty-five of the 300 (8.3%) clams under experimental conditions died.*

In September 1980, operation of Unit 2 at Arkansas Power and Light's Nuclear One power plant near Russellville had to be shut down because of an extensive invasion of the reactor's emergency cooling system by Asian Clams, *Corbicula fluminea* (Müller, 1776). The cleanup took 29 days at a cost to AP&L of 15.3 million dollars (Griffin, 1983). After the AP&L case, the Nuclear Regulatory Commission found that 10 other nuclear power plants had experienced biofouling problems because of *C. fluminea*, although not to the extent found in the Arkansas facility (Buel, 1983).

The biofouling potential of this clam species prompted the NRC, and the Electric Power Research Institute of Palo Alto, California, to sponsor the Second International *Corbicula* Symposium at Little Rock, Arkansas (hosted by AP&L and the University of Arkansas) in June of 1983. During those meetings McMahon (1983, *pers. comm.*) stressed the need for more information regarding northeastern populations of *C. fluminea*. Although the present work had begun prior to the symposium, McMahon's comments provided an added incentive for the continuation of this project assessing the growth of *C. fluminea* in West Virginia over an extended time period.

It should be added that *C. fluminea*, as an introduced species, has become widely dispersed throughout the major drainages of the United States, and that many types of industrial facilities are threatened by large accumulations of this nuisance species. For an account of the spread of this clam the reader is referred to McMahon (1982).

Materials and Methods

On 5 March 1983, 470 *Corbicula fluminea* individuals, measuring 9.0 to 15.2 mm in shell length, were collected from Mud River, West Virginia (MG92885315, USGS Topographic Map, Milton Quadrangle, W. Va. 1972) and carried to the laboratory at Marshall University in two 20 liter containers. Twenty clams were selected at random, cleaned with absorbent nylon reinforced towels (Fisher Teri® Wipers), measured individually for shell length to the nearest 0.1 mm with vernier calipers, then weighed collectively for total weight. Soft tissues were removed from these clams, blotted dry on another absorbent towel, then weighed. A baseline "condition index" (C. I.) was determined by:

$$\text{C. I.} = \frac{\text{wet soft tissue weight}}{\text{total weight}} \times 100 = \_\_\_\_\_\%$$

Both weighings were made on a Mettler Model P1000 balance to the nearest 0.01 gm. The remaining 450 clams were transferred to an unheated building where they were maintained at water temperatures of 10° to 14°C in a 50 gallon aerated aquarium containing a substrate of sand and gravel to a depth of 8.0 cm.

On 12 March 1983 (Day Zero), clams were transported to the field site at the U. S. Army Corps of Engineers Marmet Locks and Dam on the Kanawha River, West Virginia (milepoint 67.7, Kanawha River Navagation Charts, Corps of Engineers, Jan. 1975). Clams were selected randomly and segregated into 15 groups on site. The 30 clams in each group were cleaned then measured individually for shell length as described previously. Clams in each group were then weighed collectively on an Ohaus triple-beam balance for total weight to the nearest 0.1 gm. Mean lengths and weights were recorded for Day Zero.

A series of 15 cages, in three floating units (cf. Fig. 1), were used to hold clams. Each group of 30 clams was placed in a separate cage, along with a sand and gravel substrate approximately 6.0 cm deep. Each unit of five cages was then lowered into the river and secured to the outer lock wall (away from barge traffic) with an appropriate length (~ 3 meters) of 3/8 inch diameter nylon rope. Surface water temperature was recorded for Day Zero, and on each collection date (Table 1; Fig. 2A) thereafter.

After two weeks the floating unit with Cage #1 was pulled from the river and all living clams retrieved from that cage. These clams were cleaned and divided into two equivalent length subgroups. Mean lengths and weights were determined for each subgroup. One subgroup (open triangles of Fig. 2B) was returned to the laboratory for a C. I. determination. Clams of the second subgroup (open squares of Fig. 2B) were replaced in the cage and lowered back into the river. After an additional two weeks at prevailing temperatures, clams in the second subgroup of Cage #1 were retrieved, cleaned, and measured again for length and weight then returned to the lab for a C. I. determination.

The procedure for handling clams in subsequent weeks (collection schedule, Table 1) for Cages #2 thru #10 was the same as described for Cage #1. Clams collected on those dates in normal type of Table 1 (symbolized as closed circles in Fig. 2B and diagonal line bars in Fig. 2C) yielded data pertaining to increases in length, and weight, from Day Zero. Thus as the experimental time period increased, measured growth took place over widely varying temperature conditions (Fig. 2A). Clams retrieved on those dates in boldface type of Table 1 (symbolized as closed squares in Fig. 2B and dark bars of Fig. 2C) yielded data on length, and weight, increases over a two week period only, at relatively constant temperature ranges. This procedure also permitted a C. I. determination every two

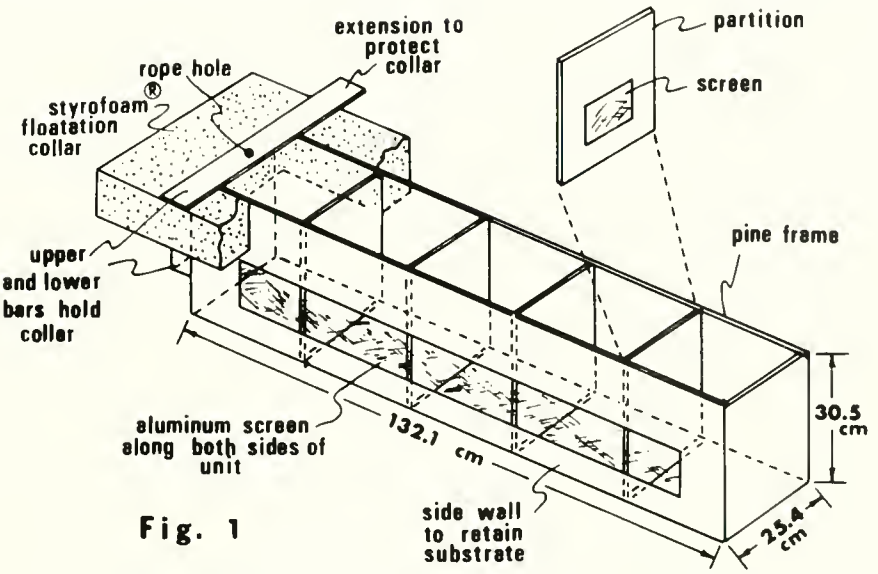

FIG. 1. Line drawing (not to scale) of field unit with five cages.

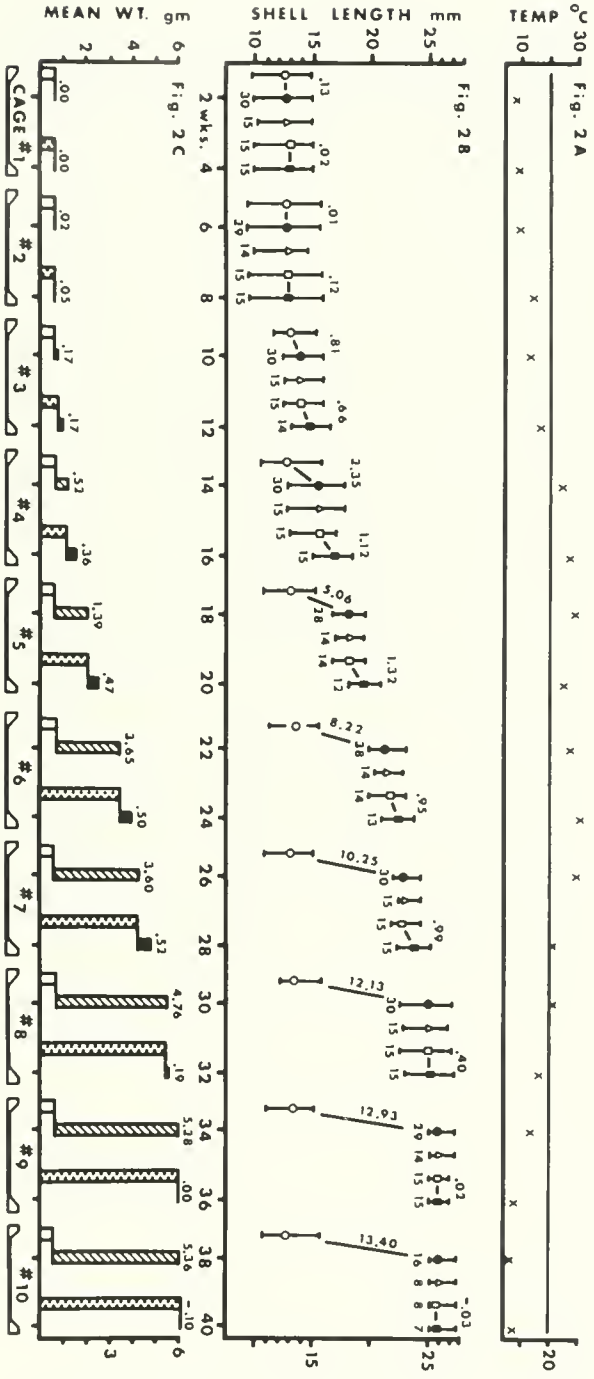

FIG. 2A. Surface water temperatures recorded within cage on day of collection.

FIG. 2B. Open circles = mean SL (shell length) on Day Zero. Closed circles = mean SL after experimental period (in weeks) designated on X-axis. Open triangles = mean SL of lab subgroup. Open squares = mean SL of field subgroup. Closed squares = mean SL of field subgroup after additional two week period in field. Vertical lines = SL range. Numbers above mean symbols = mean SL increase for period indicated along X-axis. Numbers below vertical lines = sample size of living clams.

FIG. 2C. Open bars = mean weight on Day Zero. Diagonal line bars = mean weight after experimental period. Stippled bars = mean weight of field subgroup. Dark bars = mean weight of field subgroup after additional two week period in field. Numbers above diagonal line bars = mean weight increase during experimental period (since Day Zero) indicated along X-axis. Numbers above dark bars = mean weight increase for field subgroup during two week period. Sample sizes same as in Fig. 2B. Weights of lab subgroup not shown.

weeks. Condition indices of on-site caged clams were compared with those determined for clams collected from natural stream conditions at the original collection site (Table 2).

Results

Growth of *C. fluminea*, as determined by increases in shell length, and overall weight, over a 40-week period is shown in Fig. 2 B & C. There was virtually no growth in those clams maintained in Cages #1 and #2 when water temperatures were <10°C. Cessation of growth for large clams at <10°C was also recorded for Cages #9 and #10. Noticeable growth was first observed for those clams in Cage #3 when water temperatures were ~14°C and rising. Although only negligible growth occurred during the first eight weeks, clams doubled in weight after approximately 15 weeks, but did not double in shell length until the 34th week.

Rates of increases in shell length and total weight were calculated at two week intervals to minimize the effect temperature fluctuations have on growth of *C. fluminea*. On that basis, greatest rate increases in shell length (ranging from 0.48 mm/wk to 0.66 mm/wk) were recorded for those clams maintained in Cages #4 thru #7 when water temperatures were between 24° and 30°C. Greatest rate increases in weight (ranging from 0.18 gm/wk to 0.26 gm/wk) also occurred in Cages #4 thru #7.

"Condition," defined as percentage of total weight made up by soft tissue, of experimental caged clams was comparable to that of natural stream clams (Table 2).

Twenty-five of the 300 (8.3%) clams in Cages #1 thru #10 died throughout the course of the study (Fig. 2B).

TABLE 1. Collection schedule* for *C. fluminea* in the Kanawha River, Marmet Dam, W. Va.

	Cage #1	#2	#3	#4	#5	#6	#7	#8	#9	#10
DAY ZERO	12 Mar	12 Mar	12 Mar	12 Mar	12 Mar	12 Mar	12 Mar	12 Mar	12 Mar	12 Mar
2 weeks	26 Mar									
4	**9 Apr**									
6		23 Apr								
8		**7 May**								
10			21 May							
12			**5 Jun**							
14				18 Jun						
16				**2 Jul**						
18					16 Jul					
20					**30 Jul**					
22						12 Aug				
24						**26 Aug**				
26							9 Sep			
28							**23 Sep**			
30								7 Oct		
32								**21 Oct**		
34									4 Nov	
36									**18 Nov**	
38										2 Dec
40										**16 Dec**

*Cages 11 thru 15 were invaded by a predator [muskrat(s)?] sometime between 2 and 6 December 1983. Number of survivors in these cages was too small to continue experiment beyond 16 December 1983.

Discussion

Growth-Shell Length:

That growth of *Corbicula fluminea* did not occur at temperatures of <10°C corroborates the findings of previous investigators. For example, Eng (1977), working with *C. fluminea* in California, noted that, "Growth . . . is negligible . . . when water temperature is below about 14°C." And, in the first two weeks of Welch and Joy's (1984) "cold water" experiment, when temperatures were falling from 19° to 13.5°C, clams in their two smallest designated shell length classes grew at a rate of 0.5 mm/wk. However, for the next 10 weeks of that experiment, when water temperatures ranged between 13.5° and 0.5°C, there were no increases in mean shell lengths.

Conversely, optimum growth for *C. fluminea* occurs ". . . in the mid-twenty °C range" (Mattice and Dye, 1979). That same general observation had been made earlier by Heinsohn (1958), and O'Kane (1976) for *C. fluminea* in California and Texas, respectively. More recently, Scott-Wasilk, *et al.* (1983) reported shell length increases of ~ 0.80 mm/wk for *C. fluminea* from June thru September in northern Ohio. Welch and Joy (1984) recorded mean shell length increases, uder optimum summertime conditions (21.5°-31.0°C), of 0.79, 0.86, and 0.95 mm/wk (over 12 weeks) for *C. fluminea* with initial (Day Zero) mean lengths of 13.0, 10.8, and 8.7 mm, respectively. They added that those rates compared favorably with growth rates for *C. fluminea* individuals (with similar initial shell lengths) in the west and southwest. Thus maximum increases in mean shell lengths of 0.48 to 0.66 mm/wk recorded for *C. fluminea* individuals maintained under optimum summertime conditions in Cages #4 thru #7 (Fig. 2 A & B) were anticipated. That these rates were somewhat less than recorded by Welch and Joy was not disturbing because clams in the present study had higher initial mean shell lengths (15.2 mm, open square of Cage #4 to 22.5 mm, open square of Cage #7; Fig. 2B). Since rate of shell length increase in *C. fluminea* is an inverse

TABLE 2. A comparison of condition indices between clams under experimental caged conditions (at Marmet), and similarly-sized clams under natural field conditions at the original collection site (Mud River Falls).

	Marmet			Mud River Falls*		
Date 1983	N =	SL range (mm) of sample	C.I. (%)	N =	SL range (mm) of sample	C.I. (%)
5 Mar				20	9.5–14.1	14.7
26 Mar	15	9.7–14.3	13.5			
6 Apr				25	8.5–14.8	15.0
9 Apr	15	9.3–14.5	14.3			
23 Apr	14	9.4–14.2	13.6			
7 May	15	8.8–15.3	14.1			
21 May	15	12.0–15.3	14.0			
29 May				18	12.2–14.7	12.8
5 Jun	14	12.5–15.8	12.7			
16 Jun				19	12.7–16.7	12.6
18 Jun	15	12.6–17.1	12.6			
2 Jul	15	14.3–17.8	17.6			
16 Jul	14	16.3–18.9	18.2	13	15.5–19.5	16.0
30 Jul	12	17.5–20.3	17.0			
10 Aug				8	19.0–23.0	19.3
13 Aug	14	19.7–22.1	18.1			
26 Aug	13	20.3–23.1	18.3			
9 Sep	15	22.2–23.8	17.3			
14 Sep				9	21.2–24.6	18.1
23 Sep	15	21.8–24.6	19.3			
7 Oct	15	22.3–26.1	21.2			
18 Oct				10	20.6–24.5	20.3
21 Oct	15	22.6–26.8	20.1			
4 Nov	14	24.7–26.9	19.2			
18 Nov	15	24.9–26.5	18.1			
2 Dec	8	24.8–27.5	18.3			
16 Dec	7	24.8–27.5	18.9			

*No collections beyond 18 Oct because of high water.

linear function (Mattice and Dye, 1979; Joy, in Press) rate differences between Welch and Joy's work and the present study are more likely the reflection of initial mean shell lengths rather than any intrinsic difference in growth patterns for clams in the two studies.

Growth-Weight:

As noted by Welch and Joy (1984), "Increases in weight have largely been ignored . . . as a measure of growth in *C. fluminea*." Those writers reported mean weight gains of 0.27 to 0.30 gm/wk (over 10 weeks) for "warm water" (21.5° to 31.0°C) classes of *C. fluminea* individuals with initial mean weights of 0.53 gm and 1.20 gm for the smallest and largest classes, respectively. Although not an ideal comparison because of differences in initial mean weights, clams in Cages #5, #6, and #7 (with initial mean weights of 2.2, 3.5, and 4.2 gm, respectively) exhibited similar weight gains under comparable temperature conditions (calculated over two week periods; solid bars of Fig. 2C). O'Kane (1976) reported weight gains of 0.18 gm/wk for clams with an initial weight of 3.15 gm; somewhat less than the rate of 0.25 gm/wk recorded for similarly-sized clams in Cage #6.

Weight gains noticeably lower than those found in the present study were recorded by Joy (In Press) who calculated an increase of only 0.13 gm/wk (over nine weeks) for clams with an initial mean weight of 2.6 gm. And Hartley (1981), working with *C. manilensis* (=*C. fluminea*) as a potential biological monitor for pesticides in Illinois, cited mean weight gains of 0.055 gm/wk (after 18 days) and 0.007 gm/wk (after 72 days). However, Hartley used relatively large clams (5.3 gm) maintained in much lower temperatures.

Condition Indices:

There is the question, when dealing with "caged" clams, regarding possible limiting effects brought about by artificially confining the test animals. McMahon and Williams (In Press) were convinced that *C. fluminea* individuals in

cages grew as well as their in-stream counterparts. Since it is impractical to monitor growth of marked individuals in natural populations for any length of time, another measure of determining the health or "condition" of caged individuals, relative to those in natural stream conditions, was sought. The soft tissue weight as a percentage of total weight (i.e. "condition index") determined every two weeks for caged individuals compared favorable with similarly-sized in-stream clams (Table 2). Both groups (caged and natural populations) exhibited similar C. I. patterns, with low C. I.'s occurring in May and June, and relatively high C. I.'s from mid-August to the end of the study period. Thus the argument that "caged" clams suffered no ill-effects by their confinement can be made with some conviction (and confirms McMahon and Williams' view).

There is no ready explanation for the low C. I.'s during May and June. However, it could have been indicative of an energy drain on clams preparing for spawning. Nearly all clams were gravid in the July samples, a phenomenon consistent with the findings of Bickel (1966) who reported a July spawning for *C. fluminea* in the Ohio River near Paducah, Kentucky. Still, what controls spawning in *C. fluminea* is poorly understood. Periods of ova and sperm production, and spawning, are presently being investigated in this lab.

Mortalities:

Twenty-five of 300 (8.3%) clams died throughout the 40 week experimental period (Fig. 2B). That did not include those clams originally placed in Cages #11 thru #15, which were apparently destroyed by a predator (Table 1). This mortality rate does not seem unduly high when compared to previous investigations. O'Kane (1976) lost only 6.0% of his original 340 clams over a 12 month period. Hartley (1981) recorded a low mortality (4 of 660 clams) over 72 days, and Joy (In Press) reported only seven clam deaths from a sample population of 600 over a nine week period. Welch and Joy (1984) recorded a relatively high mortality rate of 27.5% (22 of 80 clams) for clams maintained at the same river location (under temperature conditions similar to the present study) during the previous summer. They also reported a mortality of 19.0% for clams monitored during cold water temperatures. And finally, Buttner (1981) recorded high mortality rates (64%, 44% and 21% for the summers of '77, '78, and '79, respectively) for *C. fluminea* maintained in cages in catfish rearing ponds. Those ponds were subjected to Karmex, Batex, and rotenone treatments which may have accounted for the high mortality levels.

While a considerable body of literature on growth of *C. fluminea* in different geographical locales has accumulated since Villadolid and Del Rosario's publication of 1930 on juvenile clams, comparisons of growth rates are not easily made. Investigators have utilized clams of different initial sizes under diverse temperature conditions for widely varying study periods. The complexity of the problem is compounded by a lack of information on nutritional requirements of the Asiatic clam. Knight (1983) has achieved some success – with considerable effort – in identifying several algal species as potential food sources. Avenues of research regarding growth and feeding of *C. fluminea* have not been exhausted. Indeed, there is much work yet to do.

Acknowledgments

I want to thank Mr. Kenneth Welch for his invaluable assistance throughout the course of this study.

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FRESHWATER MUSSELS (UNIONIDAE) OF THE BIG BLACK RIVER, MISSISSIPPI

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ABSTRACT

*Collections of freshwater mussels made in 1980-81 along 321 km of the Big Black River of Mississippi produced 31 speeies of unionids and the Asian Clam (*Corbicula fluminea *(Müller, 1774)). This study is compared with a 1904 and 1969 survey of the unionid fauna of this river system.*

Prior to this study, the only major records of freshwater mussels from the Big Black River in Mississippi were by Hinkley (1906) and Grantham (1969). Hinkley recorded 18 species collected in 1904 near Durant, Holmes County. Grantham included the Big Black River in a statewide survey of the pelecypod fauna, but added no species new to the river, and confirmed only seven of those reported by Hinkley.

The objectives of this study were to determine the species composition of unionids in the Big Black River and to compare the present fauna with the findings of earlier workers.

Methods

During the summers of 1980 and 1981, we surveyed about 321 km of the Big Black River from the mouth at the Mississippi River upstream to Mississippi Highway 407, Montgomery County. Sand and gravel bars were searched for dead shells and riffles and shallow reaches were sampled by hand for live mussels. Voucher specimens of uncertain identifications were confirmed by the Ohio State University Museum of Zoology. The collections are deposited in the Bivalve Collection of the Mississippi Museum of Natural Science, Jackson, Mississippi.

Study Area and Habitats

The Big Black River originates in the North Central Hills of central Mississippi and flows southwestwardly for about 434 km before entering the Mississippi River 40 km below Vicksburg (Fig. 1).

The Big Black River Basin is long (248 km) and narrow (35 km) and crosses four physiographic divisions of the Coastal Plains Province

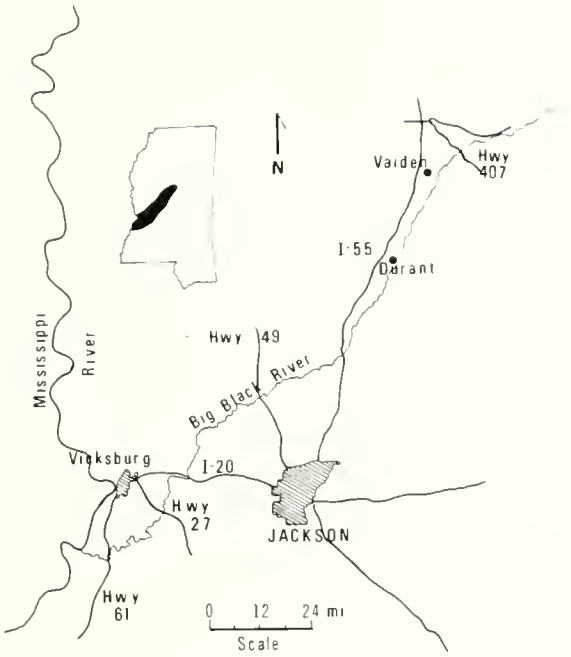

FIG. 1. Big Black River, Mississippi.

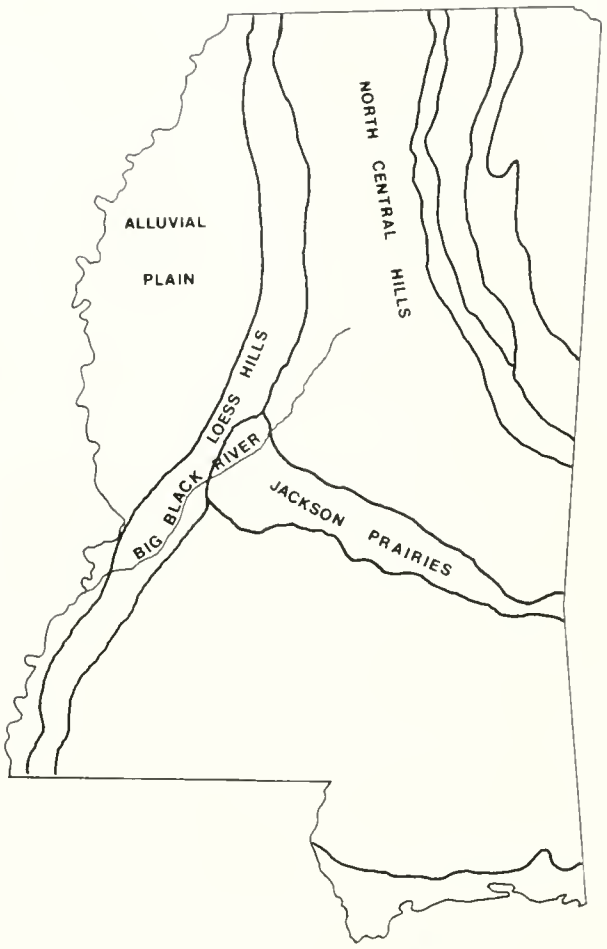

FIG. 2. Physiographic Regions of Mississippi.

(USDA, 1968): the North Central Hills, Jackson Prairies, Loess Hills, and Mississippi Alluvial Plains (Fig. 2). Landform varies from broad, sand-hill uplands dissected by numerous streams in the upper basin to steep uplands dissected by relatively deep gorges in the lower basin. About 57% of the basin is forested, the remainder is composed of cropland and pasture.

The main stem of the Big Black is a stream in good condition with relatively little pollution except for turbidity caused by agricultural runoff. Water quality of tributary streams is near excellent except for some impairment at a few point sources of pollution.

Perhaps the most striking feature of this river is the change in channel characteristics (depth, current, substratum) as it flows through the different physiographic divisions. The lower part of the river in the Alluvial Plain is wide, deep and bayou-like with muddy waters, silt and mud bottom, and little current.

In the Loess Hills above Mississippi Highway 61, the banks are steep, muddy and unstable. There is much silt and mud substratum; however the river often cuts through the loess to underlying deposits of gravel, and occasional gravel bars are encountered. Currents keep the gravel bars and riffles relatively free of silt.

The river is shallow and meandering with numerous sandbars and predominantly sand bottom in the Jackson Prairies and the North Central Hills. Gravel substratum are rare to absent.

Upriver from Vaiden, Mississippi, the river runs through a large bottomland swamp. Banks are low, heavily vegetated and the stream is narrow and deep with little current. Above this, about 40 km of the main channel has been channelized.

Results and Discussion

We collected 31 species of unionids and the Asian Clam (*Corbicula fluminea*) from the Big Black River (Table 1). Three of these (*Quadrula nodulata* (Rafinesque, 1820), *Q. cylindrica cylindrica* (Say, 1817), *Pleurobema rubrum* (Rafinesque, 1820)) were collected for the first

TABLE 1. Mussels collected from the Big Black River.

	MMNS (1980)	Hinkley (1906)	Grantham (1969)
1.	Anodonta imbecillis Say, 1829		
2.	A. grandis grandis Say, 1829		
3.	A. grandis corpulenta Cooper, 1834		
4.	Arcidens confragosus (Say, 1829	Arcidens confragosus Say	
5.	Megalonaias nervosa (Rafinesque, 1820)		
6.	Plectomerus dombeyanus (Valenciennes, 1827)		
7.	Tritogonia verrucosa (Rafinesque, 1820)	Tritogonia tuberculata Barnes	Tritogonia verrucosa
8.	Quadrula apiculata aspera (Lea, 1831)	Quadrula aspera Lea	
9.	Q. pustulosa pustulosa (Lea, 1831)	Quadrula pustulosa Lea	Quadrula refulgens
10.	Q. nodulata (Rafinesque, 1820)		
11.	Q. cylindrica (Say, 1817)		
12.	Amblema plicata perplicata (Conrad, 1841)	Quadrula perplicata Conrad	Amblema costata
13.	Fusconaia ebena (Lea, 1831)		
14.	F. flava (Rafinesque, 1820)	Quadrula hebetata Conrad	
*15.	F. cerina (Conrad, 1838)	Quadrula rubida Lea	
*16.	Pleurobema curtum (Lea, 1859)	Pleurobema curta Lea	
17.	Pleurobema rubrum (Rafinesque, 1820)		
18.	Elliptio crassidens crassidens (Lamark, 1819)		
19.	Uniomerus tetralasmus (Say, 1830)		
20.	Obliquaria reflexa (Rafinesque, 1820)		
21.	Glebula rotundata (Lamark, 1819)		
22.	Plagiola lineolata (Rafinesque, 1820)		
23.	Obovaria jacksoniana Frierson, 1912	Obovaria castanea Lea	
*24.	O. unicolor (Lea, 1845)	Obovaria unicolor Lea	Obovaria unicolor
25.	O. subrotunda (Rafinesque, 1820)		
26.	Truncilla truncata Rafinesque, 1820		
27.	T. donaciformis (Lea, 1845)	Plagiola donaciformis Lea	
28.	Leptodea fragilis (Rafinesque, 1820)	Lampsilis gracilis Barnes	Leptodea fragilis
29.	Potamilus purpuratus (Lamark, 1819)	Lampsilis purpuratus Lamark	Proptera purpurata
30.	Villosa lienosa (Conrad, 1834)	Lampsilis lineosus Conrad	
31.	Ligumia subrostrata (Say, 1831)		
32.	Lampsilis teres anodontoides (Lea, 1831)	Lampsilis fallaciosus Smith	Lampsilis anodontoides
*33.	L. radiata hydiana (Lea, 1838)	Lampsilis hydianus Lea	
34.	L. radiata luteola (Lamark, 1819		
35.	L. ovata ventricosa (Barnes, 1823)		
*36.	L. ornata (Conrad, 1835)	Lampsilis excavatus Lea	
37.	Corbicula fluminea (Müller, 1774)		Corbicula leana

* Not collected by authors.

time in the eastern drainage of the Mississippi River south of the Tennessee River.

Five of the species collected by Hinkley were not found during this survey (Table 1). With the exception of Johnson's record of a disjunct population of *Lampsilis excavata* (Lea, 1857) in the Black River system of Arkansas (Johnson, 1980), Hinkley's report of *L. ornata* (Conrad, 1835), *Pleurobema curtum* (Lea, 1859), and *Obovaria unicolor* (Lea, 1845) constitutes the only record of these species in the Mississippi River drainages. Otherwise, *P. curtum* is endemic to the Tombigbee drainage (Stansbery, 1976), while *O. unicolor* and *L. ornata* inhabit streams flowing into the Gulf of Mexico from Alabama to the Amite River in eastern Louisiana (Stern, 1976, Burch, 1975). *Lampsilis radiata hydiana* (Lea, 1838) has been collected in both the Mississippi River drainage and the Gulf Coast drainage. These species may once have existed in the Big Black, and may yet, however the presence and relative abundance of closely related or similarly appearing species (*O. jacksoniana* (Frierson, 1912), *O. subrotunda* (Rafinesque, 1820), *L. ovata ventricosa* (Barnes, 1823), *L. radiata luteola* (Lamark, 1819)) in the system suggests that the specimens may have been misidentified or mislabeled. Unfortunately we have been unable to locate and examine Hinkley's Big Black collections.

The fifth species *Fusconaia cerina* (Conrad, 1838) is virtually indistinguishable from *F. flava* (Rafinesque, 1820). Frierson (1927) believed there was no morphological evidence to separate these two species and considered *F. cerina* as a synonym of *F. flava*. Johnson (1980) also considers them to be ecophenotypes. Both forms are encountered in Mississippi with the *F. flava* form occurring in Mississippi River drainages and the *F. cerina* form in Gulf Coast streams east of the Mississippi River. The only morphological differences we have observed between

the animals of these drainages has been nacre color. The form in the Big Black River that we consider to be *F. flava* has nacre that is commonly white, with occasional individuals having a faint cream or orange-tinted nacre. This can be contrasted with the form *F. cerina* occurring in the Pearl, Pascagoula and Tombigbee drainages where bright red or pink nacre is commonly encountered with only occasional individuals having white nacre. Other features of shell anatomy are highly variable and are not useful in separating these two forms.

Grantham's 1969 monograph of Mississippi pelecypods reported seven species occurring in the Big Black and added *Corbicula fluminea* to the drainage list (Table 1). One of his records was a western range extension for the Gulf Coast species *Quadrula refulgens* (Lea, 1868). Johnson (1980) considers this species a synonym of *Q. pustulosa* (Lea, 1831). We do not concur, finding that these species differ in shell shape, nacre color, periostracum color, inflation, umbo height, and size and arrangement of pustules. Upon examination of the late Dr. Grantham's collections we found that he misidentified *Q. pustulosa* as *Quadrula refulgens*. Dr. Grantham consistently used Gulf Coast nomenclature for certain species in the Mississippi drainage, for example, *Q. refulgens* for *Q. pustulosa*, and *Lampsilis straminea* (Conrad) for *L. radiata luteola*. Grantham also reported *Obovaria unicolor* from the Big Black. It is likely that this was a similar misuse of nomenclature for *O. subrotunda;* however, we were unable to find specimens from this river system among his collections. Since Grantham concentrated his efforts in east and south Mississippi, the absence of many other species from his account of the lower Mississippi River drainages appears to reflect collecting effort in that part of the state.

One of the more interesting aspects of this survey was the change in substratum as the river flows through the different physiographic regions and the corresponding change in the makeup of the naiad fauna. The richest section of the river in terms of unionid diversity is in the Loess Hills physiographic region, roughly that stretch of river flowing between Highway 61 and Highway 49. Eight species of mussels were collected only in this general area (*Quadrula nodulata, Quadrula cylindrica, Pleurobema rubrum, Obliquaria reflexa* Rafinesque, 1820, *Fusconaia ebena* (Lea, 1831), *Truncilla truncata* Rafinesque, 1820, *Arcidens confragosus* (Say, 1829), and *Ellipsaria lineolata* (Rafinesque, 1920). Most were associated with gravel riffles and runs.

Obovaria subrotunda, O. jacksoniana, Lampsilis radiata luteola and *Glebula rotundata* (Lamark, 1819) were collected only in shallow tributaries or the main channel flowing through the Jackson Prairies and North Central Hills. *Uniomerus tetralasmus* (Say, 1831), *Anodonta grandis grandis* Say, 1829), *A. G. corpulenta* Cooper, 1834, *Anodonta imbecillis* Say, 1829, and *Ligumia subrostrata* (Say, 1831) were collected from oxbows or found dead below oxbows draining into the river.

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VARIATIONS OF SHELL MORPHOLOGY IN THE CAROLINA MARSH CLAM, *POLYMESODA CAROLINIANA*, FROM SOUTHEASTERN UNITED STATES (CORBICULIDAE)

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ABSTRACT

Polymesoda caroliniana (Bivalvia: Corbiculidae) representing 15 populations from the Gulf and south Atlantic coasts of the U.S. were collected. Six morphometric measures of the shell were made on each clam collected. Physical characteristics of each site were also measured. Visually, at least three shell morphs were found; the very angular shell type from Yankeetown, Florida, the broad type from Redfish Point, Louisiana, and the common oval form from most other locations. When multivariate statistics were used (Principle Components) some differentiation of populations based on shell shape was apparent. The broad type from Louisiana was statistically different from the others. Other populations formed a continuum with overlap between populations. All populations were readily identified as P. caroliniana *based on internal shell characters. No differentiation occurred between south Atlantic U.S. populations and Gulf populations. Populations which differed from the typical form were generally from non-typical habitats. No physical characteristic of the site was correlated with different shell characters.*

The Carolina Marsh Clam, *Polymesoda caroliniana* (Bosc, 1801) is found in brackish marshes from Texas to Virginia (Abbott 1954; Morris 1973) and is remarkably tolerant of a variety of stressful conditions including variations in salinity (van der Schalie 1933; Gainey 1976a, b; Gainey and Greenberg 1977; Deaton 1981, 1982), anoxia (Pamatmat 1979), and desiccation (Olsen 1976; Duobinis-Gray and Hackney 1982). *Polymesoda caroliniana* is found in poorly flooded habitats (Subrahmanyam *et al.* 1976; Duobinis-Gray and Hackney 1982) and in permanently flooded communities (Swingle and Bland 1974). Reproduction varies from once a year in well-flooded habitats (Olsen 1976) to several times a year in poorly flooded marshes (Hackney 1983). With such diverse habitats over a large geographic range, the species exhibits variations in shell morphology due likely to genetic and/or environmentally induced mechanisms.

The following study examines populations of *P. caroliniana* from throughout the geographic range and from different environments and determines 1) if variations in shell morphology exist, and 2) if variations followed geographic patterns or were associated with physical characteristics of the site.

Study Sites

Estuaries from Maryland to eastern Texas were examined for populations of *P. caroliniana*. Fifteen populations representing different parts of the geographic range and populations from "non-typical" *Polymesoda* habitats were chosen for study. The general location of these sites is shown in Figure 1 and specific site descriptions are as follows:

Site 1. Intertidal marsh dominated by *Juncus roemerianus* on the southwest side of North Carolina Highway 1100, 16 km south of Wilmington, NC, in New Hanover County.

Site 2. Intertidal swamp along the inner reaches of an unnamed tidal creek 0.5 km south of Ness Creek, a tributary of the Northeast Cape Fear River in New Hanover County, North Carolina.

Site 3. Intertidal marsh dominated by *Spartina alterniflora* on Battery Island, North Carolina, in Brunswick County. The population was located 20 m from the Cape Fear River on the NW side of the island. The population was found only in a small area of the high intertidal zone.

Site 4. Intertidal marsh dominated by *J. roemerianus* in

FIG. 1. General geographic location of collection sites along the Gulf and Atlantic coasts of the United States. Insert shows the location of the three collection sites in the Cape Fear estuary, North Carolina.

Faver-Dykes State Park in Flagler County, Florida. The specific site was 20 m east of the boat dock and picnic area.

Site 5. Subtidal in a tidal creek with an average depth of 10 cm at low tide. The collecting site was under the bridge on U.S. Highway 1 which separates St. Johns County and Flagler County, Florida.

Site 6. Intertidal, well-flooded marsh dominated by *J. roemerianus* approximately 6 km west of Yankeetown, Florida, Levy County, adjacent to a picnic area.

Site 7. Fringing intertidal marsh dominated by *J. roemerianus*, approximately 0.75 km from the entrance to Ft. McAllister State Park on state road 144 in Chatham County, Georgia, approximately 26 km south of Savannah, Georgia.

Site 8. Subtidal location along the marsh edge approximately 5 m from Site 7.

Site 9. Subtidal habitat in a shallow pond on a marsh dominated by *J. roemerianus*. The site is approximately 0.7 km NW of the Louisiana State Fisheries and Wildlife Station at Fearman Bayou in Vermillion Parish, Louisiana.

Site 10. Intertidal marsh dominated by *J. roemerianus* on a small island located at the mouth of the Jourdan River, approximately 5 km north of Bay St. Louis, Mississippi, Hancock County.

Site 11. Well-flooded intertidal marsh dominated by *J. roemerianus* where old U.S. Highway 90 crosses Davis Bayou, east of Ocean Springs, Mississippi in Jackson County.

Site 12. Clams were found exposed on the edge of an intertidal marsh dominated by *J. roemerianus* and *Sagittaria* spp. on the most southern of the Twin Islands in the Pascagoula Estuary, Jackson County, Mississippi.

Site 13. Intertidal marsh dominated by short form *J. roemerianus* and short form *S. alterniflora* near Bayou La Batre, Alabama, in Mobile County. The marsh was off Highway 188 where Coden Bayou and Portersville Bay intersect.

Site 14. Intertidal marsh dominated by *J. roemerianus* located where a tidal creek crosses U.S. Highway 17, 25 km north of the intersection of U.S. Highway 17 and Highway 41 North of Charleston, South Carolina, in Charleston County.

Site 15. Intertidal marsh dominated by *J. roemerianus* located in Bellfontaine marsh south of Davis Bayou which is east of Ocean Springs, Mississippi in Jackson County.

Methods and Materials

At each site the following site characteristics were measured as follows. Salinity with a refractometer (AO model 10423) ± 0.5‰. The

water sample was squeezed from the sediment where the clams were collected. Soil compaction was determined with a standard soil penetrometer (FSN 6635-679-5761). Between 3 and 10 measurements were made depending on the variation at each site. Soil moisture was determined by drying triplicate soil samples at 103°C and organic content by ignition of triplicate samples at 600°C for 6 h. Soil texture was determined using the hydrometer method (Bouyoucos 1927, 1928).

At least 10 clams were randomly collected from each site. The goal was 20 clams from each site, but clams were rare at a few sites. Only live clams were used in the study. Clams were frozen, and later after thawing, the soft tissues were removed from the shell. The following measurements were made on each clam using calipers accurate ± 0.2 mm: *Length* as the maximum distance from the anterior to the posterior portion of the shell; *width* (i.e., height) as the distance from the dorsal margin of the umbo to the ventral margin at a 90° angle from the length; *maximum width* (height) as the greatest distance that could be measured from the dorsal margin of the umbo to the ventral margin; *width* (thickness) as the maximum distance from the umbo on the right valve to the same place on the left valve. Shell weight was determined after air drying at 103°C to a constant weight (± 0.05 g) on an Ohause top loading balance (B 300D). The area of the shell was a measurement determined by tracing the outside margin of the left valve on paper and then measuring the area of the tracing with a compensating Polar Planimeter (KE 62 0005) accurate ± 0.01 cm².

Statistical Analysis

Combinations of the measured variables were regressed on one another using the GLM package in SAS 82.3 (SAS, 1982). Variables which were linearly related ($r^2>0.8$) were used to produce ratios which were used in the Principle Components Analyses. All variables were standardized. This was necessary to satisfy the assumptions of the test and also eliminated site specific size related bias. Thus, shell morphology not shell size was the factor tested. Initially all ratios of variables that were linearly related were used in the PRINCOMP package in SAS 82.3 (SAS, 1982). When two ratios with a high degree of correlation to one another (>0.8) were found, one of the pair was omitted from the final analysis following general guidelines for the procedure. The principle components which allowed the greatest differentiation of populations were used to produce plots which showed morphological similarities and differences among populations.

Results

A preliminary investigation of shell morphology found some differences in shell morphology among six populations (Hackney and Moorse 1984). Furthermore, these variations were regular enough to be quantified by as few as 10 clams from a population (Hackney and Moorse 1984). Based on the 15 populations examined in this study, three distinctive shell types were visually recognizable (Fig. 2). Broad clams (Fig. 2A) were collected only at Site 9 in Louisiana, a sub-

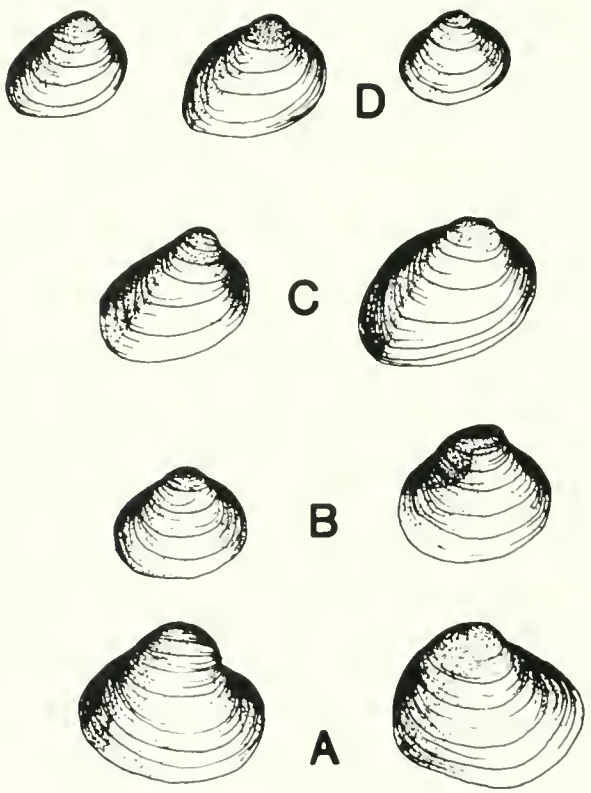

FIG. 2. Population variation of shell morphology in *Polymesoda caroliniana*. Type A represents Site 9 in Louisiana, type B the normal shell type, type C the highly angular morph best represented by the Yankeetown, Florida population, and type D the typical mixture of slightly angular and typical oval forms found at most sites.

tidal population. Even small clams (<20 mm) showed the broad or elongated shell, characteristic of this population. Clams in this population commonly exceeded 40 mm in maximum length with a few reaching 60 mm. The most common form of *P. caroliniana* was the oval type (Fig. 2B). This form dominated most sites and was present in all populations except sites 6 and 9. Clams at site 6 had very angular shells (Fig. 2C) and could easily be separated from other populations. Specimens from this population were confirmed as *P. caroliniana* (R. T. Abbott, personal communication). The angular characteristic was found in all size classes. Most sites contained clams which included oval as well as some slightly angular shells (Fig. 2D). In these collections larger clams tended to be more angular. The only other collection which was visually different was one from site 2. This site was dominated by low salinity, low pH water from a blackwater river (Northeast Cape Fear River). Shells were thin and golden in color.

Color of the internal shell was also examined. Shells were found which contained purple and/or golden yellowish coloration. In some shells the typical white color was completely covered by one or more of these colors. Neither the color or extent of coloration was a consistant characteristic of any population and was not useful in distinguishing populations from one another.

Three populations (Sites 1-3) from different habitats were collected from within the Cape Fear River estuary, NC, and represent a range of salinity from fresh to nearly marine (Table 1). There was some separation of these populations based on Principle Components composed of area/weight and area/width ratios (Fig. 3). There was overlap of the population (Site 1) from the typical *P. caroliniana* habitat, i.e. *Juncus roemerianus* marsh, with the salt marsh population (Site 3) and the tidal swamp population (Site 2). Shells from sites 3 and 2 could be

TABLE 1. Physical characteristics of sites and numbers of *Polymesoda* clams measured.

Site Number	Number of Clams Measured	Pore Water Salinity 0/00	Mean Penetrometer Index	Mean % Soil Moisture	% Organic Content	% Sand	% Silt	% Clay
1	126	8	30	79	52	43	7	49
2	61	0	7	83	58	68	17	15
3	61	26	123	42	8	54	8	38
4	10	2	101	81	26	40	5	55
5	10	0	20	45	5	86	6	8
6	10	6	23	28	75	64	2	34
7	12	5	130	54	10	92	8	0
8	20	5	11	34	5	88	8	4
9	28	3	0	68	9	61	31	7
10	19	8*	14	42	11	39	35	14
11	19	4*	20	64	36	24	24	19
12	20	12*	21	40	9	42	27	22
13	20	15*	19	32	6	64	13	17
14	9	20	11	75	21	66	29	5
15	20	15	9	76	24	66	29	5

* Salinity determined by silver nitrate titration and conversion of chloride to salinity. Salinity 0/00 = 0.030 + (1.8050 x chlorinity 0/00).

separated from one another with a high degree of certainty (Fig. 3). Shells from the *Spartina alterniflora* dominated salt marsh (Site 3) were heavy and rounded while those from the tidal swamp (Site 2) were round and light. Genetic differences have been demonstrated for other mollusk species along environmental gradients (Levington 1973; Koehn *et al.* 1976).

When shells from all Atlantic coast populations were examined the same shell characteristics (area/weight and area/width) again provided the best resolution via Principle Components Analysis (Fig. 4). Shells from sites 4 and 14 had about the same area/width values as site 3 while sites 7, 8, and 5 were intermediate to sites 1 and 2 (Fig. 4). Site characteristics at sites 14 and 3 were similar in that they were more saline (Table 1), but site 4 was a low salinity site and clams at this site were subtidal. Shells from sites 4 and 14 could be statistically separated from sites 2 and 5 with a high degree (95%) of certainty.

Populations from the Gulf of Mexico were best segregated from one another by different principle components, namely weight/maxwidth and height/width ratios. Shells from sites 9 and 11 were easily separated from one another (Fig. 5) and there was only a slight degree of overlap between sites 9 and 10 (Fig. 5). Shells from site 9 (Fig. 2A), as noted previously, were morphologically distinct, as were those from site 6. Shells from sites 6 and 9 exhibited a high degree of overlap (Fig. 5) even though their appearance was different (Figs. 2A and 2C). Most of the remaining Gulf populations exhibited a high degree of similarity (Fig. 5).

When all 15 populations were combined one principle component from the Gulf of Mexico analysis and one from the Atlantic coast emerged as the two most important (Fig. 6). Separation of populations previously noted, i.e. sites 9 from 11 and 2 from 3 remain (Fig. 6). Also shells from sites 14 and 4 were distinctly different from sites 11 and 6. Shells from site 9 were again distinctly different from all other populations (Fig. 6). Although separation is possible between some of the populations when viewed as a whole they form a continuum (Fig. 6).

Discussion

Populations separated by great distances, or a

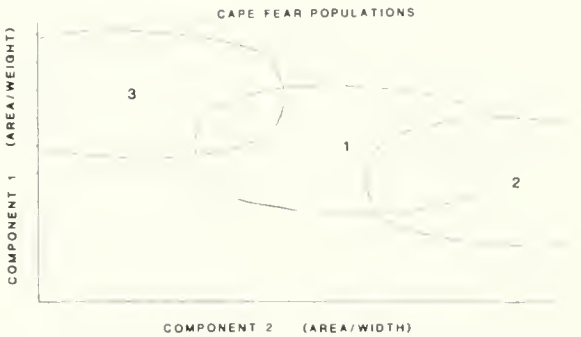

FIG. 3. Principle Components plots of the Cape Fear populations. Component 1 was the most important variable in distinguishing between populations while component 2 was second. Site numbers represent means of each population for each component. Elipses represent 95% of all members of the population. Scale on the X and Y axis are irrelevant.

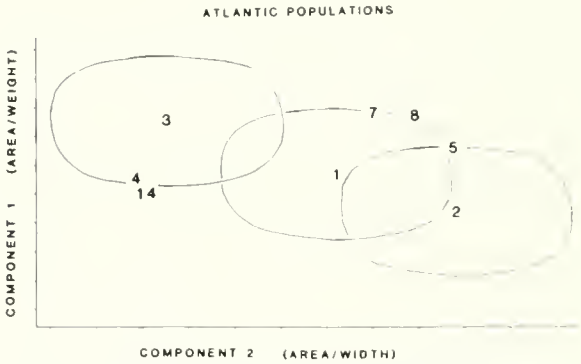

FIG. 4. Principle components plot of all Atlantic coast populations. Means of sites are represented by their respective numbers. Elipses drawn around each mean represent 95% of all members of each population. Populations without elipses contain the same 95% limits as those represented by populations 1, 2 and 3.

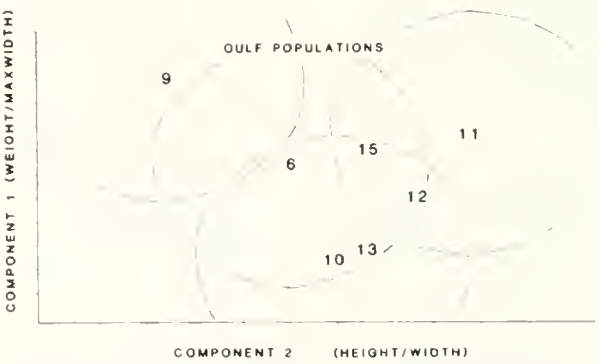

FIG. 5. Principle components plot of all Gulf populations. Site numbers represent means for each. Elipses drawn around means of populations from sites 9, 10, and 11 represent 95% of the population. Other populations contain the same size elipses.

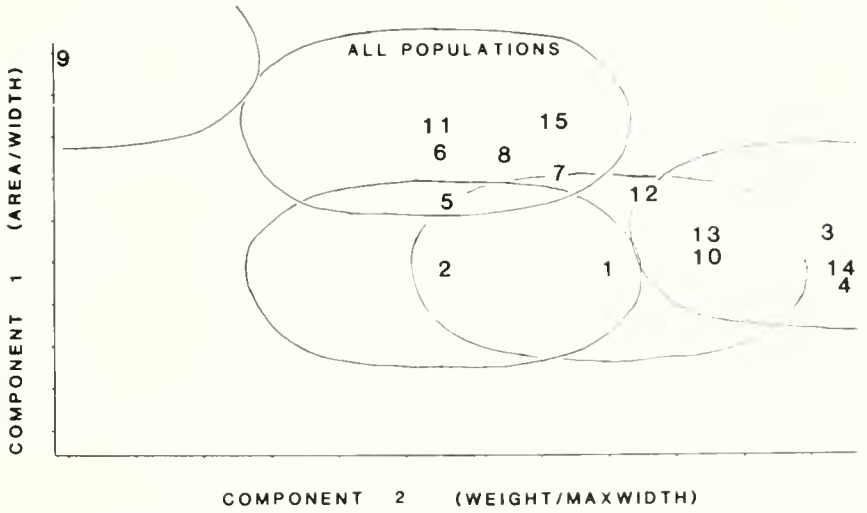

FIG. 6. Principle components plot of all populations. Site numbers represent the means of each. Elipses drawn around means represent 95% of all clams in each population. Elipses are not drawn around all populations but are the same size for each.

barrier such as the peninsula of Florida, might be expected to have begun the process of genetic differentiation. *Polymesoda* populations do not show such differentiation, at least as reflected in shell morphology. With the exception of population 9 (Louisiana) there was almost total overlap between the Atlantic and Gulf populations (Fig. 6). Variations in shell morphology have been shown to exist in *Littorina saxatilis* and were correlated with genetic differences related to environmental pressures (Janson and Ward 1984). Differences may occur between mollusk populations separated by only one meter if environmental pressures are different, such as in a surf zone (Janson and Ward 1984). Most of the populations examined in this study were from similar habitats, i.e. irregularly flooded *Juncus* marshes with thick root mats in acidic soil. Such rigorous environments are likely to exert strong selection pressures on filter feeding bivalves and genetic differences are masked by the need of populations to conform critical features such as shell shape and structure. This is character convergence at the species level.

The three populations from the Cape Fear River show a clinal trend from high to low salinity (Fig. 3). Shell morphology has been shown to change with distance up an estuary in the case of *L. saxatilis* (Newkirk and Doyle 1975). Such a trend suggests salinity as a factor related to shell shape, but the trend does not continue if all populations are examined (Fig. 6 and Table 1). Measuring salinity one time during collection of clams may not be enough to correctly describe a habitat.

Populations which were readily discernible either through principle components analysis or visual means were from atypical habitats. Population 9 was from a soft substrate in a subtidal pond. Population 6 contained very angular clams and was also from a soft substrate and well-flooded habitat. Population 2 was in a tidal swamp where the pH of the water is very low for long periods of time due to the influence of a nearby blackwater river. A variety of environmental factors can affect shell growth and development in bivalves (Tevesz and Carter 1980; Burky 1983) including temperature, pH, dissolved ions in the water, hydrography, and substrate. Morphological differences between populations may not be detected through electrophoretic studies (Janson and Ward 1984) because they may not be the result of genetic differences between populations or the wrong allozymes were selected for study.

Although *P. caroliniana* populations have been identified which can be distinguished from others, through visual as well as statistical means, the important characters for identification are the narrow, external ligament, the three subequal cardinal teeth, the one anterior lateral tooth and the one posterior lateral tooth

which does not extend to the posterior adductor scar (Heard 1982).

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GROWTH AND OPTIMUM SEEDING TIME FOR THE HARD CLAM, *MERCENARIA MERCENARIA* (L.), IN COASTAL GEORGIA

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ABSTRACT

Instantaneous growth rates of the hard clam, or Quahog, Mercenaria mercenaria *(L.), in Georgia were studied to determine the best time to seed clams to obtain maximum growth. Clam growth occurs in two distinct phases. During the first phase, juveniles grow continuously throughout the year with most rapid growth in the spring and declining growth through the summer, fall and winter. In phase two, the growth of clams approximately 1½ years old oscillates with decreasing amphitude over time. Because, in Georgia, juvenile clams grow most rapidly during the spring that time or late winter is considered the best for seeding to obtain maximum yields.*

Introduction

The coastal waters of Georgia support approximately 450,000 acres of salt marsh or approximately 33% of the salt marshes along the Atlantic seaboard. During the early part of the century, these marshes supported a large oyster and small clam fishery. Today, the oyster industry is almost non-existent (Harris, 1980), and clamming is sporadic (Walker *et al.*, 1980; Walker, 1984a). This is unfortunate because most of the coastal waters of Georgia are relatively free of pollution and are suitable for the commercial culturing of shellfish.

As more northern waters are closed to shellfishing due to pollution (National Marine Fishery Service, 1977), the opportunity to use the coastal waters of Georgia for shellfish culture increases. Hard clams, or the Northern Quahog, *Mercenaria mercenaria* (Linnaeus, 1758), grow rapidly throughout the year in southern waters (Menzel, 1963; Eldridge *et al.*, 1976; Walker, 1984b). In South Carolina, clam growth occurs throughout the year but varies seasonally (Eldridge *et al.*, 1976). In Florida, growth is most rapid in fall and spring, slower in winter and slowest in summer (Menzel, 1963; 1964). In contrast, growth in northern waters ceases during winter when water temperature cool to 5 to 6°C (Loosanoff, 1939). Most rapid growth is in the summer when water temperatures reach 20°C (Ansell, 1968).

The culture of hard clams may be one means of increasing shellfish production in Georgia. Clams planted at 6-mm in shell length at a density of 509/m² within predator exclusion cages grow to commercial size (44.4-mm in shell length) within 17 months with good survival rates (Walker, 1984b). However, to assure high survival rates, crab larvae which entered cages had to be removed monthly, until clams reached a shell length of approximately 20-mm. At larger sizes, they were immune to predation by small crabs.

By determining the optimum time for seeding clams, it may be possible to decrease the time required to obtain a marketable product. Eldridge *et al.* (1979) observed that clams in South Carolina grew best in spring and fall and recommended seeding in the fall. Earlier Eldridge *et al.* (1976) reported that clam grew best in spring and summer. These conflicting reports suggest that fall may not be the best planting time for clams in southern waters.

The purpose of the research reported here was to determine the optimum seeding time for obtaining maximum growth of hard clams in the coastal waters of Georgia.

Materials and Methods

The growth of three stocks of hard clams from

Georgia, Massachusetts and Virginia stocks were compared. Local clams, collected from near Cabbage Island, Savannah, Georgia, were shipped to Virginia Institute of Marine Science (VIMS), Eastern Shore Laboratory, Wachapreague, Virginia, where they were spawned. Their offspring were returned to Georgia when they had grown to a shell length of 10.4 ± 1.2 (SD) mm. VIMS also supplied a fast growing stock of Virginia clams with a mean shell length of 11.0 ± 1.2 (SD) mm. A third stock (12.8 ± 1.8 mm), also selectively bred for rapid growth, was obtained from Martha's Vinyard Shellfish Group, Oak Bluffs, Massachusetts.

The clams were planted on November 30, 1980 near Cabbage Island (Fig. 1) in 1 × 1 × 0.3 m cages constructed of 6-mm vexar plastic. Three replicate cages per stock were seeded at a density of 1000 clams/m². The cages were buried in a sandy substrate to a depth of 0.15 m and the enclosed bottom was layered with 5 cm of gravel aggregate in an attempt to minimize crab predation (Castagna and Kraeuter, 1977). The corners of the cages were attached to 1 m stakes.

All cages were sampled seasonally over two years by sieving all of the sediment through a 5-mm screen. The clams were counted and their shell length measured (the longest possible measurement, i.e., anterior-posterior) to the nearest 0.1-mm with vernier calipers. Sediment and clams were then returned to their respective plots. Two cages (1 × 1 × 0.5 m) constructed of 3-mm-mesh vexar plastic attached to a frame of 13-mm steel reinforcement rods were divided into nine compartments of 0.11 m² each. Cages were buried to a depth of 0.25 m on an intertidal sandflat near Cabbage Island, Georgia in May 1982 (Fig. 1). In June 1982, 6-mm seed clams supplied by Aquaculture Research Corporation were planted and maintained at the following replicate densities: 56, 111, 222 and 333 clams/0.11m² or the equivalent to 509, 1009, 2018 and 3027 clams/m², respectively. The center compartment of the cage was seeded with approximately 500 clams to replace those that died. In the other cage, clams with an average shell length of 39 mm, were planted at the following densities: 10, 25 and 45 clams/

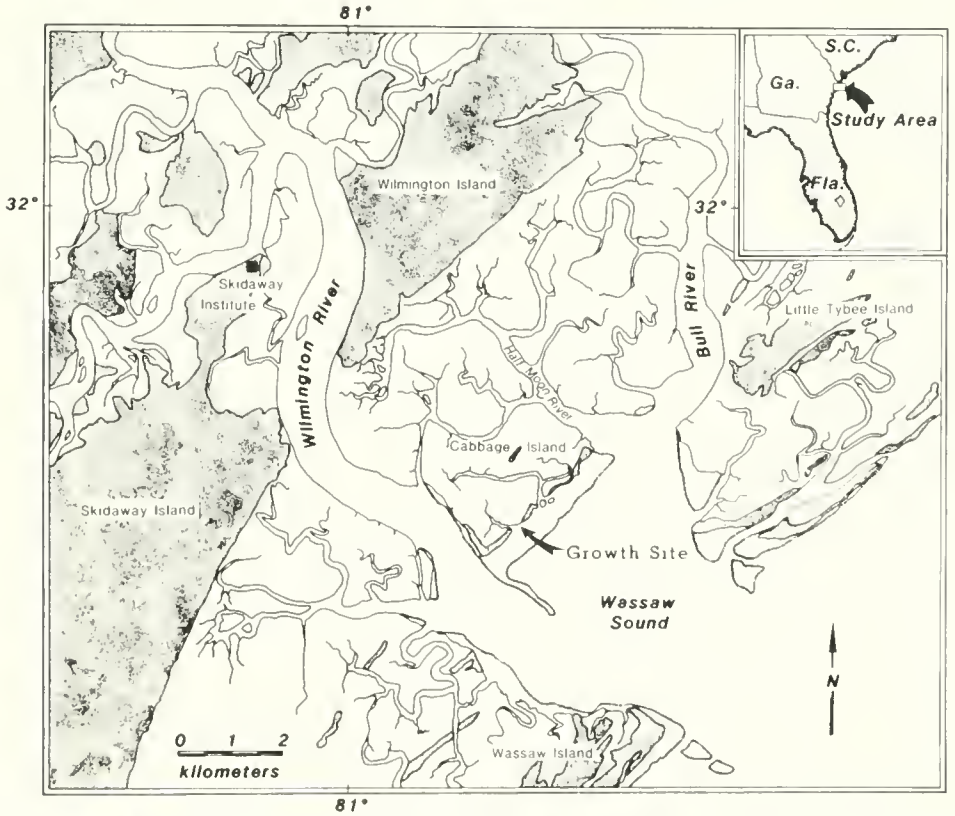

FIG. 1. Map of Wassaw Sound, Georgia showing experimental growing site at Cabbage Island.

0.11m² or the equivalent to 91, 227 and 409 clams/m².

Cage I (6-mm clams) was sampled monthly while Cage II was sampled seasonally. In each case clams, crabs and sediment to a depth of 0.25 m were sieved through a 5-mm screen. Clams were counted, the shell length of a subsample (N = 70) measured and clams were added if needed to keep the density constant in each compartment. Crabs were identified to species, measured for carapace width and discarded. After January 1983, Cage I was sampled seasonally because survival had remained at approximately 100% for several months (Walker, 1984b).

Clams (N = 174) from field populations located near Cabbage Island were used to determine the relationship between shell length and ash-free dry weight (AFDW). After they were measured to the nearest mm, the flesh was removed and dried to constant dry weight at 80°C for 48 hours. Ash weight was determined by combusting the sample at 475°C for 16 hours and ash-free dry weight determined by difference. The resulting equation is: g AFDW = 0.00000726 (shell length in mm) 2.98, $r^2 = 0.99$.

The instantaneous growth value G equals the instantaneous increase in meat weight over given time intervals (seasons in this case). G is calculated as Ln(Wt/Wo) where o and t represent the beginning and end of each time interval. The ash-free dry weight value (W) was determined by taking the mean shell length at each sampling and inserting that value into the above shell length to mean individual meat ash-free dry weight regression equation. An example is given in Table 1.

Results

Instantaneous growth values (G) for the three clam stocks are given in Table 2 and values obtained at different clam densities per age class are given in Table 3. Older clams grew well in fall and spring, with moderate growth in summer and poor growth in winter. The growth of the 0 to 1 year old clams did not show the characteristic reductions in growth during the summer; however, the reduced growth in winter is apparent. This phenomenon is observed both in the stock seed clams' first summer (Table 2; Summer 1981) and in the seed clam density experiment (Table 3; Summer of 1982 and 1983). However it is not observed among older clams or in the second year of the stock experiment.

Clam growth in Georgia appears to go through two phases (Fig. 2). During the first phase, clams 0 to approximately 1½ years in age appear to grow in a linear fashion with most rapid growth in the spring and decreasing growth through the following seasons. In the second phase, clam growth oscillates with decreasing amphitude over time.

TABLE 1. Growth data for the hard clam, *Mercenaria mercenaria*, cage planted with yearlings at a density of 91/m².

Date	Mean shell length in mm	Mean Individual Wgt in g AFDW	Instantaneous Growth (G)
June 1982	39.9	0.4284	
			0.15
September 1982	42.0	0.4991	
			0.32
December 1982	46.7	0.6847	
			0.07
March 1983	47.7	0.7293	
			0.19
June 1983	50.8	0.8799	
			0.08
September 1983	52.2	0.9514	
			0.18
December 1983	55.3	1.1331	
			0.06
March 1984	56.5	1.2079	
			0.18
June 1984	60.1	1.4485	
			0.10
September 1984	62.2	1.6085	
			0.14
December 1984	65.1	1.8425	

Discussion

The two phase growth pattern for hard clams in southeastern Atlantic coast waters can be explained in terms of poor growth conditions in winter and the reproductive cycle of clams. Clams in Georgia and South Carolina exhibit a distinct bimodal reproductive cycle (Pline, 1984; Eversole *et al.*, 1980) with spawning occurring from spring well into fall. The peak spawning periods of Georgia clam populations is in May and October (Pline, 1984), while in South Carolina peaks are in May to June and in September to October (Eversole *et al.*, 1980). According to Belding (1931), clams in Massachusetts reach sexual maturity at shell lengths of 32 to 38 mm. Thus maturity is related to size rather than age. In South Carolina populations, a small percent of males and females spawned at an approximate average shell length of 18 to 22 mm (Eversole *et al.*, 1980; Fig. 2; Eldridge *et al.*, 1979; Table 4); however, most clams did not spawn until they reached an average size of 28 to 32 mm. Thus, until clams are approximately 1 to 1½ years old, energy is used for growth rather than reproduction resulting in the seasonally linear decline clam growth between spring and winter. When sexual maturity is reached, clam growth in summer is reduced because some clams continue to spawn while others regenerate biomass lost during spring spawning. The result is cyclic growth.

The results of this work are comparable to other studies of hard clam growth in southeastern United States. In this area, clams grow year around with most rapid growth in spring and fall (Eldridge *et al.*, 1976, 1979; Menzel, 1963). *Mercenaria mercenaria* seed clams, obtained from a Connecticut hatchery, and grown in coastal Florida grew well in spring and fall with slow growth in winter and least growth in summer. However, with naturally occurring sets of *Mercenaria campechiensis* Gmelin seed clams growth was best in spring and fall, rapid in summer and slowest in winter (Menzel, 1963). In Georgia, *Mercenaria mercenaria* grew best in spring and fall with little growth in winter

TABLE 2. Instantaneous growth values per season per hard clam, *Mercenaria mercenaria*, stock from fall 1980 to fall 1982. Data is from Walker (1984a).

STOCK	Fall 80	Win 81	Spr 81	Sum 81	Fall 81	Win 82	Spr 82	Sum 82	Fall 82
Georgia	0.26	0.91	1.10	0.75	0.44	0.25	0.38	0.28	0.33
Massachusetts	0.05	0.47	0.80	0.55	-	-	-	-	-
Virginia	0.48	1.02	1.27	0.85	0.34	0.25	0.21	0.20	0.19

TABLE 3. Instantaneous growth values (G) per season per hard clam, *Mercenaria mercenaria*, density per age class from summer 1982 to fall 1984. Instantaneous growth values for the seed clams are from data reported in Walker (1984b) and those for the one year old clams (yearlings) are from unpublished data.

DENSITY	Sum 82	Fall 82	Win 83	Spr 83	Sum 83	Fall 83	Win 84	Spr 84	Sum 84	Fall 84
Seed Clams										
509/m^2	2.15	1.75	0.48	0.82	0.68	0.34	0.05	0.33	0.18	
1009/m^2	2.38	1.64	0.40	0.74	0.56	0.20	0.04	0.18	0.03	
2018/m^2	2.13	1.74	0.40	0.72	0.23	0.10	0.08	0.15	0.02	
3027/m^2	2.18	1.62	0.39	0.67	0.01	0.18	0.05	0.00	0.03	
YEARLINGS										
91/m^2	0.15	0.32	0.07	0.19	0.08	0.18	0.06	0.18	0.11	0.14
227/m^2	0.17	0.31	0.16	0.19	0.11	0.19	0.05	0.16	0.10	0.09
409/m^2	0.21	0.27	0.12	0.18	0.13	0.20	0.03	0.14	0.10	0.06

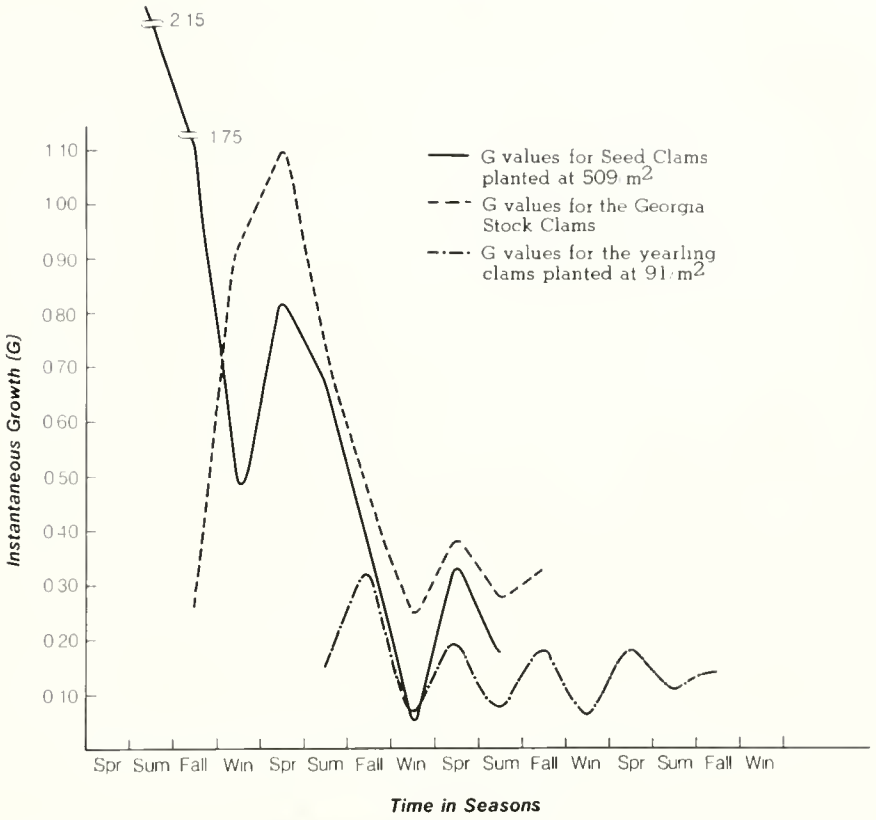

FIG. 2. Growth of hard clams, *Mercenaria mercenaria*, grown in predator exclusion cages on Cabbage Island, Wassaw Sound, Georgia.

(Godwin, 1968) while no clam growth data was obtained from the summer period, growth in August was approximately 10% of the total obtained during the experiment. *Mercenaria mercenaria* seed clams from a North Carolina hatchery which were planted in coastal South Carolina grew best in spring and fall, with least growth in winter (Eldridge *et al.*, 1979). In an earlier study, clam growth was reported best in spring and summer (Eldridge *et al.*, 1976).

These conflicting reports of clam growth patterns in South Carolina can be explained if one recognizes that there are two seperate phases of clam growth. For the first study (Eldridge *et al.*, 1976), clam growth was determined over 15 months compared to 33 months in the later study (Eldridge *et al.*, 1979). Assuming that the ash-free dry weight to shell length regression equation can be applied to those in South Carolina, the instantaneous growth values for the two South Carolina clam studies, based on shell lengths reported, are given in Table 4 and 5. This data shows that the growth patterns of South Carolina clams are similar to those in Georgia (Table 3; Fig. 2) over comparable time periods. In Eldridge *et al.* (1979), growth with time (33 months) shows that clam growth is best in fall and spring; however, if one examines only the first 15 months of the study, one would conclude that clams grew best in summer and fall.

Data presented in this report and that above suggest that optimum clam growth in Georgia and South Carolina depends upon age of the clam and planting time. From set to approximately 1½ years of age, clams grow well in spring, summer and fall depending upon seeding time, but do not grow well in winter. Older clams grow well in spring and fall, moderately in summer and poorly in winter.

Planting time may be an important factor in clam growth and in survival. Eldridge *et al.* (1979) recommended seeding South Carolina seeding areas at 300 clams/m² in fall. Based on the results of my studies which show that clam

TABLE 4. Instantaneous growth values (G) per season as calculated from clam growth data for clams planted at 290/m² in Clark Sound, South Carolina as reported in Table 3 of Eldridge *et al.* (1976).

Date	Mean Shell length in mm	Mean Individual Wgt in g AFDW	Instantaneous Growth (G)
March 1974	17.29	0.0354	
			1.07
June 1974	24.78	0.1036	
			0.90
September 1974	33.51	0.2547	
			0.41
December 1974	38.47	0.3842	
			0.25
March 1975	41.81	0.4924	
			0.31
June 1975	46.34	0.6691	

TABLE 5. Instantaneous growth values (G) per season as calculated from clam growth data for clams planted intertidally at 290/m² in Clark Sound, South Carolina as reported in Table 4 of Eldridge *et al.* (1979).

Date	Mean Shell length in mm	Mean Individual Wgt in g AFDW	Instantaneous Growth (G)
June 1975	13.86	0.0183	
			0.88
September 1975	18.62	0.0442	
			0.92
December 1975	25.33	0.1106	
			0.63
March 1976	31.25	0.2068	
			0.64
June 1976	38.77	0.3932	
			0.18
September 1976	41.12	0.4686	
			0.22
December 1976	44.34	0.5867	
			0.12
March 1977	46.15	0.6609	
			0.33
June 1977	51.56	0.9197	
			0.08
September 1977	52.91	0.9933	
			0.03
December 1977	53.36	1.0187	
			0.08
March 1978	54.77	1.1010	

growth during the 0 to 1½ year stage does not decline appreciably during the summer, I recommend seeding in late winter or early spring. If planted in early spring, clams will pass through three seasons of good growth before reducing growth in the winter. Furthermore, if planted in early spring or late winter, clams may grow to a sufficient size to prevent their predation by newly metamorphosed crabs which enter the cages. Blue crab, *Callinectes sapidus* Rathbun, spawning occurs between early May and October in Chesapeake Bay (Van Engle, 1958), from March to September in Georgia (Palmer, 1974) and from February to October in Florida (Tagatz, 1968). The peak spawning of blue crabs is from June to October. Mud crabs, *Panopeus herbstii* (Milne-Edwards), spawn from late spring through summer in South Carolina with greatest numbers of newly metamorphosed crabs occurring in July and August (Dame and Vern-

burg, 1982) and from February to October in Florida with peak spawning in June and October (Tagatz, 1968). Thus, clams planted in late winter or early spring may grow to a size sufficient to prevent predation by newly metamorphosed crabs before the peak spawning season of crabs is reached.

Acknowledgments

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ANATOMY OF *OXYLOMA NUTTALLIANA CHASMODES* PILSBRY

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ABSTRACT

Shell characteristics, anatomical features of reproductive organs, radula and jaw, pigmentation of body and habitat of the pulmonate, succineid gastropod, Oxyloma nuttalliana chasmodes *are deseribed from the University of Washington campus, Seattle, King County, Washington.*

H. A. Pilsbry (1948) described *Oxyloma nuttalliana* subspecies *chasmodes* from its shell. He reported the subspecies from only the type locality, Stockton, California. In early August, 1983, I collected from the bases of short grasses, on the wet ground of the unshaded shore of Union Bay, at the edge of the campus of the University of Washington, Seattle, King County, Washington, a succineid gastropod which I have identified as *O. nuttalliana chasmodes* Pilsbry after comparing the shell with characters as described and figured by Pilsbry (Pilsbry, 1948, pp. 795-796, Fig. 426) and with the holotype (our Fig. 1, E, F) and paratypes (our Fig. 1, C, D) from the collection of the Academy of Natural Sciences of Philadelphia, no's. 5609 and 5609a.

Anatomical features, pigmentation of the body, as well as shell characters need to be employed in the identification of succineid gastropods. I am describing shell, body features and anatomy of the above identified subspecies assuming the anatomy is similar to those of the snails of the shells described by Pilsbry.

Shell: Amber-colored, translucent, very fragile, imperforate, broadly ovate, composed of up to three whorls separated by a sharply incised suture (Fig. 1, A, B). Range in height of eight shells of this series is 13.3 mm to 8.2 mm; range in width 7.0 mm to 4.7 mm. Dimensions and ratios of dimensions of shells are recorded in Table 1. A knoblike nuclear whorl tops the short spire; whorls increase rapidly in size resulting in an elongate ultimate whorl. Nuclear whorl finely wrinkled, punctate (Fig. 2). Irregularly-spaced longitudinal striations fine on lower part of nuclear whorl increase gradually, becoming coarser on ultimate whorl. Aperture broadly ovate, occupies about 80% to 85% of entire height of shell. Peristome sharply edged; thin callus on ultimate whorl above the aperture; whitish columella follows inner border of peristome, curves as it disappears into the ultimate whorl.

Dimensions of the holotype and paratypes also are recorded in Table 1. The height attained by shells of that series is 16.7 mm. The difference in height of the two series may be attributable to a difference in time of summer when collected. The larger, more mature snails may not survive later than sometime in July, therefore, those from the Seattle site, collected in August, probably do not represent maximum size for the species.

Body and Mantle Surfaces: (Fig. 3). Body wall cream-white, transparent, irregularly tuberculate. Some individuals sparsely, others more darkly, pigmented. Pigmentation of dorsal body surface consists of fine (small) black flecks extending from anterior end of head to junction of mantle and body wall. Mid-dorsally on the head black flecks of indistinct bands form an ill-defined triangle, narrowing to a band between the superior (posterior) tentacles, dividing and continuing as a double band mid-dorsally the length of the body. On either side two bands parallel the double median band. Surface of superior tentacles flecked. Pigmentation of lateral body wall consists of spots of fine (small) flecks forming an indistinctly outlined band.

Genital aperture, approximately 1.0 mm in length, surrounded by a white, tumid lip, is situated on anterior right-hand side of body. On either side a pedal groove, continuous from labial palp to posterior tip of body, separates foot from lateral body wall; pedal groove paralleled by a less pronounced suprapedal groove.

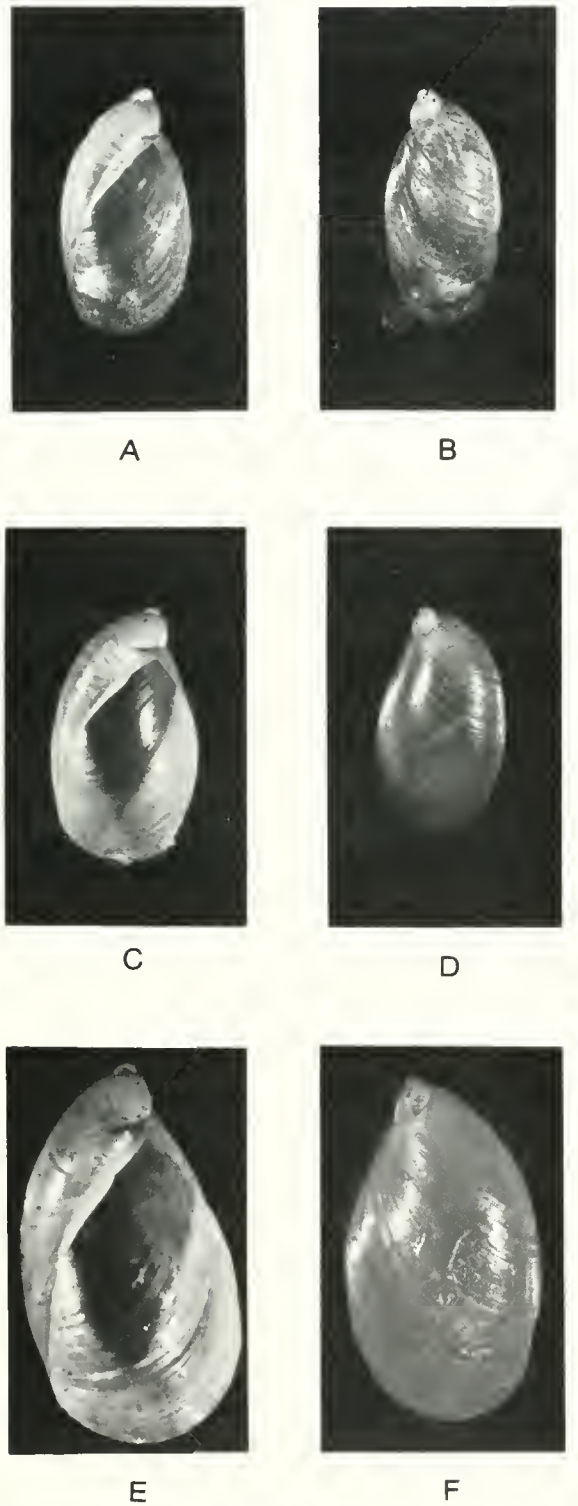

FIG. 1. Shells of *Oxyloma nuttalliana chasmodes* Pilsbry: **A, B,** Locality, Seattle, Washington, (Height, 11.4 mm); **C, D,** Paratype (Height, 12.8 mm); **E, F,** Holotype (Height, 16.5 mm).

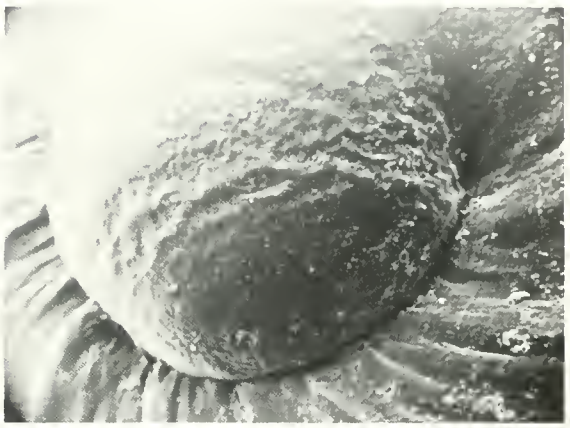

FIG. 2. Scanning-electron-photomicrograph of nuclear whorl of *Oxyloma nuttalliana chasmodes* Pilsbry.

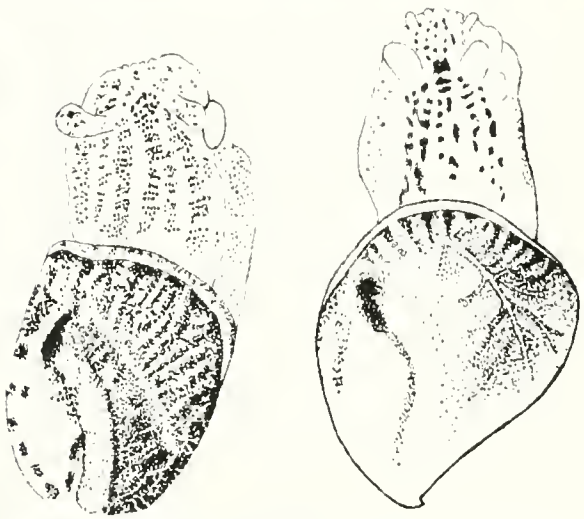

FIG. 3. Pigmentation patterns of head, body and mantle of *Oxyloma nuttalliana chasmodes* Pilsbry.

Shallow, vertical grooves incise the suprapedal and pedal grooves and body wall producing shallow scallops along margin of body wall especially when animal is in a somewhat contracted state. Sole of foot cream-white, unpigmented.

Mantle collar flecked with black pigment. Along anterior margin of mantle are patches of black pigment from which streaks extend posteriorly becoming diffuse over the mantle surface. In mature snails these streaks are concentrated between pulmonary blood vessels. The main pulmonary vessel is variably outlined by the pigment (Fig. 3). Flecks are scattered over the light yellow nephridium. An elongate black blob on the left anterior nephridial margin is followed by

TABLE 1. Dimensions of shells of *Oxyloma nuttalliana chasmodes* Pilsbry. The measurements are of eight shells of the Seattle, Washington, locality, Field no. D.S.F. 554; and of the holotype and nine paratypes of the type locality, Stockton, California. In the 4th column of measurements are listed the ratios of the width of the shell over its height. In the last 3 columns are listed the ratios of the height of the aperture over the height of the shell, width of aperture over width of shell, width of aperture over height of aperture.

	No. of Whorls	Height	Width	Width/ Height	Height of Aperture	Width of Aperture	H. Ap./ H. Shell	W. Ap./ W. Shell	W. Ap./ H. Ap.
Field #554	3	13.3 mm	6.7 mm	.503	10.5 mm	6.1 mm	.789	.910	.580
Union Bay, campus	3	12.7	7.0	.551	10.4	6.2	.818	.885	.596
of University of	2 1/2	12.6	6.2	.492	10.1	5.0	.800	.806	.495
Washington,	2 1/2	11.9	6.8	.571	10.2	5.7	.857	.838	.558
Seattle,	2 3/4	11.4	6.4	.561	8.3	5.5	.728	.859	.591
Washington	2 3/4	10.6	6.0	.566	8.6	5.0	.811	.833	.581
	2 1/2	9.6	5.5	.572	7.7	4.6	.802	.836	.597
	2 1/4	8.2	4.7	.573	6.6	3.8	.804	.808	.558
Range (8 shells)		8.2-13.3	4.7-7.0	.503-.573	6.6-10.5	3.8-6.2	.728-.857	.806-.910	.495-.591
Median		11.4-11.9	6.2-6.4	.561-.566	8.6-10.1	5.0-5.5	.802-.804	.836-.838	.580-.581
Holotype	2 1/2	16.5 mm	10.0 mm	.606	14.5 mm	8.5 mm	.878	.850	.586
Paratypes:	2 3/4	16.7	9.5	.568	13.7	8.0	.820	.842	.583
	2 1/2	16.5	8.8	.533	14.4	7.6	.872	.863	.527
Type locality	2 1/4	16.1	8.1	.503	13.6	7.2	.844	.888	.529
Stockton,	2 1/4	15.7	9.3	.592	13.0	7.5	.828	.806	.576
California	2 1/4	12.8	7.7	.601	10.8	6.5	.843	.844	.601
	2 1/2	12.8	7.1	.554	11.0	6.2	.859	.873	.563
	2 1/4	11.3	6.7	.592	9.7	6.0	.858	.895	.618
	2 1/4	10.3	5.7	.553	8.9	5.2	.864	.912	.584
	2 1/4	7.5	4.6	.613	6.5	4.0	.866	.869	.615
Range (10 shells)		7.5-16.7	4.6-10.0	.503-.613	6.5-14.5	4.0-8.5	.820-.878	.806-.912	.527-.618
Median		15.7-16.1	8.1-8.8	.568-.592	13.0-13.6	7.2-7.5	.859-.864	.869-.873	.584-.586

lesser patches or by a narrow, indistinct or a continuous band along the nephridial margin. Other patches of pigment are scattered over the left-hand side of the mantle.

Reproductive Organs: (Fig. 4). Albumin gland light cream-colored, triangular, composed of fine acini, enclosed within a thin, transparent, unpigmented sheath. Seminal vesicle elongate, subequally bilobed terminally, enclosed within a thin, transparent sheath speckled with black pigment. The darkly pigmented hermaphroditic duct joins the seminal vesicle to form the fertilization sac from which diverge the oviduct and the sperm duct which leads into the prostate gland. Prostate gland light cream-colored, ovate, elongate, enclosed by a thin, transparent, non-pigmented or sparsely flecked sheath, composed of acini which are coarser than those of the albumin gland. Vas deferens slightly peppered with black pigment. As the vas deferens approaches the penis from the prostate gland it follows the penis along its dorsal surface and enters the penial sheath distally. Within the penial sheath the vas deferens becomes the coiled epiphallus, enters the penis subterminally resulting in a penial appendage. Penial appendage elongate, digitiform and recurved. Penis coiled in a half turn before giving off appendage (Fig. 4, A, B). Penial retractor muscle, a white band, pierces the penial sheath at its distal end to be attached to the epiphallus.

Vagina, longer than the penis, straight and non-pigmented. Spermatheca large, inflated. Spermathecal duct transparent, wide, stout as it approaches and enters the vagina terminally. Oviduct highly convoluted, enters the vagina distally, ventral to the spermathecal duct (Fig. 4, C).

Radula and Jaw: The radula is composed of many rows of teeth and numerous teeth to a row. The number of rows in four radulae examined ranges from 76-86. The ratios of marginals to laterals approaches 1:4 and 1:5 (Table 2) which is within the range of other species of *Oxyloma* as reported: *O. retusa* (Lea) (Franzen, 1963, Table II, p. 89), *O. salleana* (Pfeiffer) (Franzen, 1966, Table II, p. 65), *O. haydeni* (W. G. Binney) (Franzen, 1964, Table II, p. 78) and *O. deprimida* Franzen (Franzen, 1973, Table 2, p. 71).

Structural details of individual teeth resemble

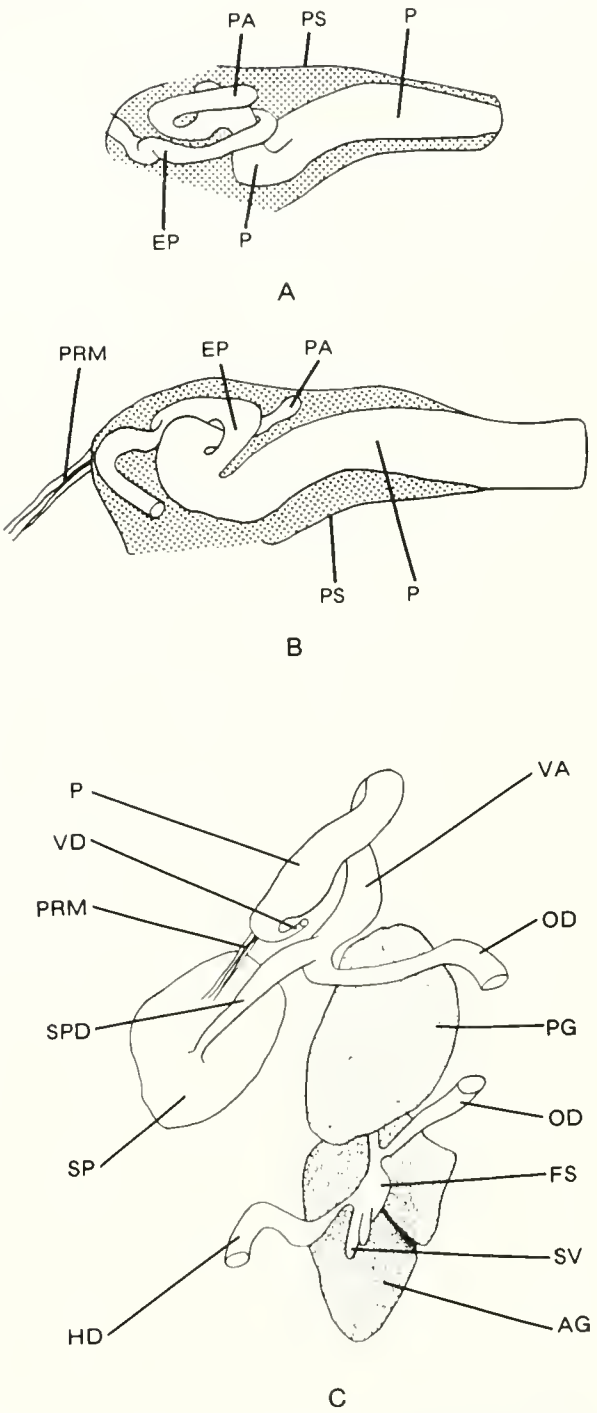

FIG. 4. Drawings of genital organs of *Oxyloma nuttalliana chasmodes* Pilsbry. **A, B,** P, penis; PA, penial appendage; EP, epiphallus (shown inside of penis sheath cut open); PRM, penial retractor muscle. **C,** P, penis; VD, vas deferens; PRM, penial retractor muscle; SPD, spermathecal duct; SP, spermatheca; HD, hermaphroditic duct; VA, vagina; OD, oviduct; PG, prostate gland; FS, fertilization sac; SV, seminal vesicle; AG, albumin gland.

TABLE 2. Formulae of representative rows of teeth of *Oxyloma nuttalliana chasmodes* Pilsbry from four specimens; Field no. DSF 554, Seattle, Washington.

Slide	No. of Rows of Teeth	Row	M	L	C	L	M
1	80	31	30	6	1	6	31
		32	31	6	1	6	31
2	82	23			1	9	34
		24			1	9	36
		30	35	8	1		
3	86	25	36	8	1		
		28	38	7	1		
4	76	27	25	5	1		
					1	6	25

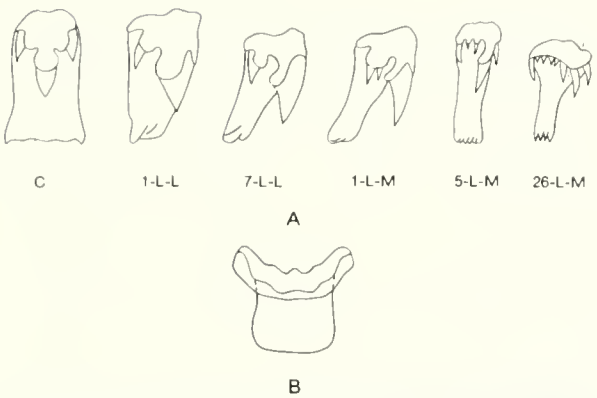

FIG. 5. A, Representative radula teeth of *Oxyloma nuttalliana chasmodes* Pilsbry. C, central tooth; 1-L-L, 1st left lateral; 7-L-L, 7th left lateral; 1-L-M, 1st left marginal; 5-L-M, 5th left marginal; 26-L-M, 26th left marginal. B, A jaw of *Oxyloma nuttalliana chasmodes* Pilsbry.

those of the genus in general (Fig. 5, A). The central tooth has a broad basal plate which has a pointed or bluntly rounded projection on either side. The pointed mesocone, somewhat variable in length, does not extend to the lower margin of the basal plate. A shorter, pointed ectocone flanks the mesocone on either side. The laterals have a large, pointed mesocone which, also, is not as long as the basal plate. The single ectocone, sometimes divided into two—especially of the more lateral teeth—is pointed; a short, pointed endocone may be present. The marginals, smaller than the laterals, have a long, slender basal plate which is characteristic of the genus *Oxyloma* (Quick, 1933:296, Fig. 1, *Oxyloma (Succinea) pfeifferi* "Rossm."). Of the cusps of the marginals the mesocone is the largest, the endocone shorter and pointed. The ectocone of the two, sometimes only the first and also the third, medial-most marginals is divided into two unequal cusps of which the lateral-most is the larger. Rarely a marginal whose ectocone is divided into three cusps appears between two with the ectocone divided into two cusps. The ectocone of the more lateral marginals is divided into three and as many as six cusps of which the outermost is curved and the largest.

The features of the amber-colored jaw are typical of the genus (Fig. 5 B). A prominent median fold projects anteriorly and is flanked on either side by a broadly rounded fold. Posteriorly the margin of the collar has a fold on either side of a median indentation.

I have not sufficiently examined shells and soft anatomy of succineas identified as *Oxyloma nuttalliana* (Lea) to determine whether or not *O. nuttalliana chasmodes* Pilsbry should be a subspecies or a valid species. Further studies, including geographic distribution and habitats, are needed to make such a determination.

Acknowledgments

National Science Foundation Grants-in-Aid No's. NSF GI8000 and NSF GB2715 provided laboratory equipment. Scanning-electron photomicrographs were the courtesy of Dr. M. J. Nadakavukaren, Illinois State University, Normal Illinois, Dr. George M. Davis, Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania, lent shells of the museum collection. Dr. A. Byron Leonard, University of Kansas, Lawrence, Kansas, read the manuscript and offered helpful suggestions.

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PSEUDOTORINIA BULLISI, NEW SPECIES (GASTROPODA: ARCHITECTONICIDAE) FROM SUBTROPICAL WESTERN ATLANTIC

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The species we describe herein was first mentioned by Merrill (1970), in his unpublished study of the Atlantic Architectonicidae. The senior author is completing a study of the Indo-Pacific species of Architectonicidae and needs an available description of this species for purposes of comparison with some closely related species of the Indo-Pacific. We place the species in the genus *Pseudotorinia* Sacco, 1892, based on the revision by Bieler (1985). Terminology of shell sculpture follows Bayer (1940:224) and Bieler (1984:455).

Pseudotorinia bullisi, *new species*

Fig. 1

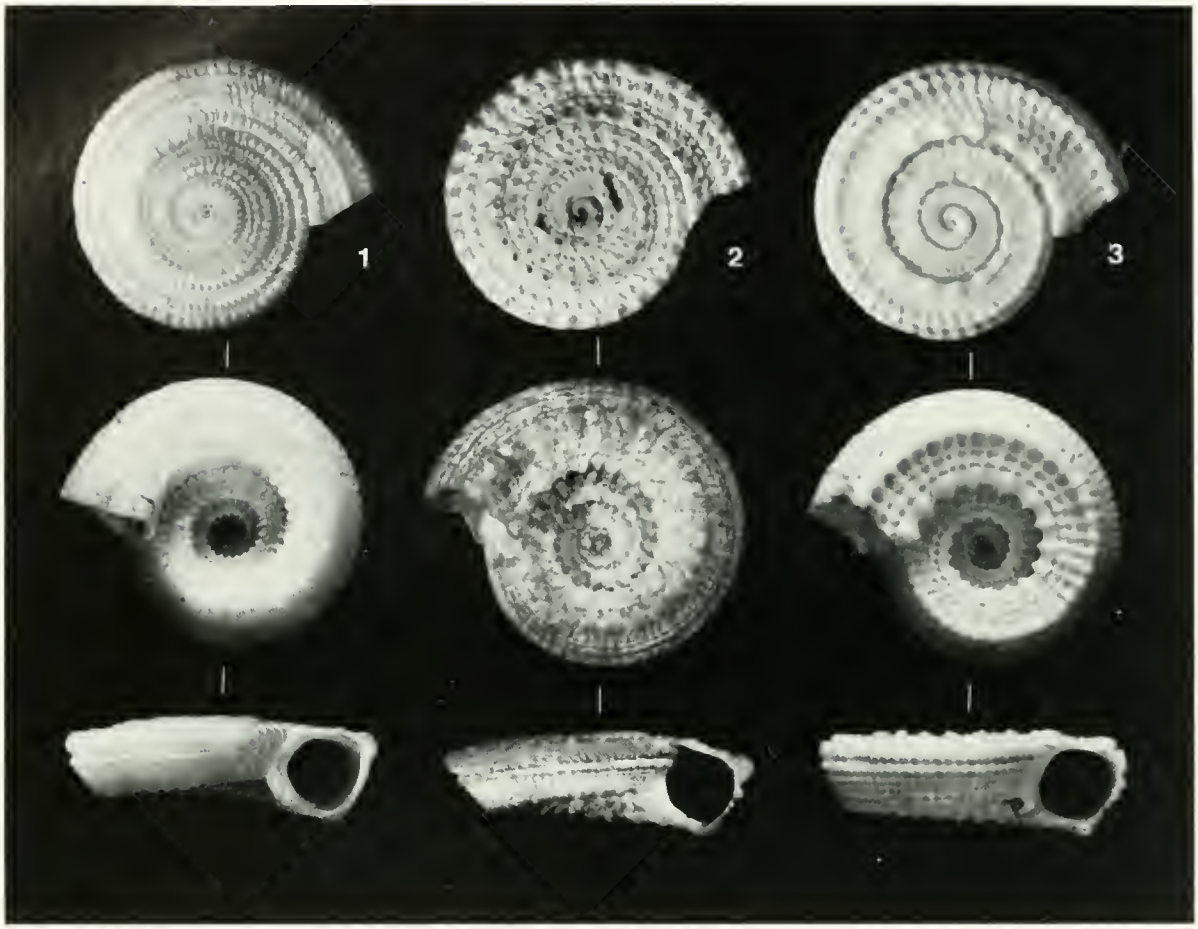
Description: Shell small, solid, with a maximum diameter of 10.2 mm and height 3.6 mm, upper surface flattened, with only a weakly channeled suture; base slightly convex and obliquely angled to about halfway, then flattened on to the umbilicus. Color whitish, irregularly mottled with light-brown, or uniform light-cream. Whorls up to 4⅛, strongly angulated, tightly coiled and joined at the midline of the prominent peripheral cord. Protoconch small, smooth, anastrophic, and after emerging, continuing for about ½ whorl, then forming a distinct varix, with 2 whorls of the emerging protoconch clearly visible from dorsal view. Dorsal spiral sculpture is composed of very strong subsutural and peripheral cords, and a prominent penultimate cord between, with shallow excavations on either side; 2 minor cords and (on larger specimens) several threads lie within the excavation between the sutural and penultimate cord. Basal spiral sculpture includes an infraperipheral cord with a deep narrow excavation between it and the peripheral cord, a very strong cord (basal keel) centrally located at the angulation where the base flattens, a strong crenulated umbilical cord, and 2 weaker cords between the central cord and the umbilical cord; approximately 8 weak threads are formed on the base between the infraperipheral cord and the basal keel. Numerous faint axial lines cut the entire surface of the shell. All cords are strongly elevated, and evenly nodulose. Umbilicus widely open (39-46% of the shell diameter), the walls marked with scaly axial lines. Aperture angular, the peripheral edge slightly bulging and the sides straight. Operculum and animal unknown.

Dimensions:

	Maximum diameter	Height	Teleoconch whorls	Umbilical width	Protoconch diameter
Holotype	10.2 mm	3.6 mm	4⅛	4.1 mm	0.62 mm
Paratype 1	4.0	1.2	2⅝	1.8	0.62
Paratype 2	4.9	1.6	2⅞	2.2	0.62
Paratype 3	4.2	1.6	2⅝	1.6	0.62

Remarks: The shell characters of *Pseudotorinia bullisi* place it near *P. numulus* (Barnard, 1963) of the Indian Ocean (fig. 2, first published photograph of that species); *P. numulus* has a larger protoconch (0.70-0.76 mm), and there are 3-5 well-developed cords below the infraperipheral which are lacking or reduced to occasional threads in *P. bullisi.*

In the Atlantic, the *Pseudotorinia architae* (Costa, 1841) complex displays similar shell



FIGS. 1-3. **1**, *Pseudotorinia bullisi* n. sp. (holotype USNM 819925; greatest diameter 10.2 mm). **2**, *Pseudotorinia numulus* (holotype of *Heliacus numulus* Barnard, 1963; SAM A9125; greatest diameter 4.5 mm). **3**, *Pseudotorinia retifera* (holotype of *Discohelix (Discosolis) retifera* Dall, 1892; USNM 83695; greatest diameter 4.4 mm).

characters (fig. 3 shows the type of *P. retifera* (Dall, 1892), a Pliocene representative of that group from Western Atlantic waters). The suture is not channeled in *P. bullisi* as in *P. retifera*, and the major spiral cords are more elevated and more coarsely nodulated, with the axial markings less prominent. In *P. retifera* the dorsal penultimate cord is closer to the peripheral cord and not as deeply excavated between. As in *P. numulus*, *P. retifera* has 3 well-developed cords below the infraperipheral which are reduced or lacking in *P. bullisi*. The umbilical cord is stronger in *P. retifera*, but the basal keel is weaker. The upper part of the base is more convex in *P. retifera*, and more obliquely angled in *P. bullisi*.

Types: Holotype and Paratype 1 of *Pseudotorinia bullisi* are in the National Museum of Natural History, Washington (USNM 819925 and 500298), and paratypes 2 and 3 in the Museum of Comparative Zoology at Harvard University, Cambridge (MCZ 262982). The type locality (holotype and paratypes 2 and 3) is *R/V Oregon* station 518, about 90 miles southwest of Pensacola, Florida (29°23.2'N. Lat.; 88°03.0'W. Long.), at a depth of 82 meters. Paratype 1 is from the Smithsonian University of Iowa Expedition 1918, Barbados station D.3, on a sandy bottom off Pelican Island in 137-146 m.

Range: The four known specimens are from off Florida and Barbados in depths of 82-146 m.

Etymology: Pseudotorinia bullisi is named for Mr. Harvey R. Bullis, who formerly headed a Bureau of Commercial Fisheries Exploratory Base at Pascagoula, Mississippi. Mollusk material sent by Mr. Bullis from his exploratory missions greatly enhanced Merrill's (1970) study of the Atlantic Architectonicidae.

Acknowledgments

We are indebted to Dr. Terrence M. Gosliner, formerly at the South African Museum, Cape Town, for the loan of the holotype of *Heliacus numulus*, and to Mr. Warren C. Blow, Department of Paleobiology, National Museum of Natural History, Washington, for the loan of the holotype of *Discohelix retifera*. Photographs were taken by Mr. Victor E. Krantz, National Museum of Natural History.

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A COMMENT ON STROPHITINAE GORDON, 1984 (UNIONIDAE, BIVALVIA)

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The history of the suprageneric taxonomy of unionid bivalves was traced by Heard and Guckert (1971) and by Davis and Fuller (1981). Haas (1969a, b) provided the latest comprehensive supraspecific monograph of the Unionacea but his classification was questioned by Heard and Guckert (1971) and Davis and Fuller (1981). Heard and Guckert (1971:336) noted that *Strophitus* Rafinesque, 1820, is "more correctly considered as a single group unlike any other subfamily", but included *Strophitus* in the Anodontinae (Heard and Guckert, 1971:340). Davis and Fuller (1981) did not discuss *Strophitus*.

Gordon (1981:58) in discussing the unionids of Arkansas created the new tribe Strophitini, for *Strophitus* Rafinesque, 1820. Gordon (1985:8, in footnote to Table 1) raised the Strophitini to subfamilial status, but omitted any discussion or justification for his action. He did not present any arguments about the relationships of this new subfamily to the other subfamilies in the Unionidae. However, neither the taxonomic validity nor the method of publication of Gordon's name Strophitini or Strophitinae are at issue here.

Gordon was apparently unaware of a previous use of Strophitinae. Starobogatov (1970:69, 287) erected a new subfamily Strophitinae in the family Lampsilidae for *Strophitus* Rafinesque, 1820. The following translation of Starobogatov's (1970:287) justification for his new subfamily is provided for those who do not have access to the original Russian publication:

> Subfam. Strophitinae Starobogatov. subfam. n.
>
> The shell has a weakened or rudimentary hinge. The beak sculpture consists of lirae (ribbing) which run in almost parallel lines of growth and turn abruptly upward in the rear. The marsupial pouches occupy the external half of the gills completely. Secondary water tubes during pregnancy bear the young. Each ovisac is divided by transverse partitions into a series of chambers. Growth is even, the glochidia do not parasitize fish.

Therefore, the correct citation of Strophitinae (as well as Strophitini, ICZN Article 36) is Strophitinae Starobogatov, 1970.

Acknowledgments

I thank James Quinn and Robert Robertson for reviewing the manuscript and commenting on the nomenclature in this paper. Ruth Griffith provided the English translation of the Russian text on Strophitinae; and Cynthia Bogan typed the manuscript.

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DISTRIBUTION OF *LAMPSILIS POWELLI* (LEA) (BIVALVIA: UNIONACEA)

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Lampsilis powelli (Lea, 1852) is a rare and poorly known freshwater mussel associated with the Interior Highlands or Ouachita Mountains of western Arkansas. This species was not included in Burch (1975). In the three published reviews of Arkansas Bivalvia, it was synonymized under *Actinonaias ligamentina* (Lamarck) by Call (1895) and overlooked by Gordon, *et al.* (1980) and Gordon (1981). Subsequently, *L. powelli* was monographed by Johnson (1980) including distributional information based on published accounts and some museum material. Examination of museum specimens, published accounts, and recent collecting has enabled us to better delineate the known distribution of this species.

The type locality is the Saline River, here restricted to Benton, Saline County, Arkansas. In addition to Lea's specimens (USNM 85042), topotypes were collected by H. E. Wheeler and R. E. Call (UMMZ 91080 and MCZ 5548, respectively). Outside Arkansas, Call (1887) reported it from the Spring River at Baxter Springs, Cherokee County, Kansas (MCZ 5550), included a brief description, and compared it to *Actinonaias ligamentina*. Scammon (1906) similarly described a specimen from the Neosho River at Oswego, Labette County, Kansas. Simpson's (1914) locality information appears to be mainly erroneous. Utterback's (1916) and Isely's (1925) records (Neosho basin) were based on identifications from L. S. Frierson (the White River record in Utterback [1917] was a misprint for the 1916 account). Particularly notable are Isely's comments (p. 111) in reference to his specimens:

"52. *Lampsilis powellii* (Lea)– Mr. Hill reports this species from the Illinois River and has sent me a number of specimens. Frierson suggests that Hill's specimens are either

powellii or an undescribed species; he also places some of them near *L. ligamentina* examples of the Neosho as probably *powellii*." *Lampsilis rafinesqueana* Frierson (1927) was described from these Illinois River, Oklahoma, specimens. The holotype (female) and a male from the Elk River, McDonald County, Missouri (probably the "*L. powelli*" in Utterback, 1916) were illustrated in Frierson (1928). Call's (1887) and Scammon's (1906) descriptions for their *L. powelli* specimens are readily identifiable as *L. rafinesqueana* (confirmed by examination of Call's voucher, MCZ 5550). The distinctive raying of the latter species may be obscured or obliterated in older specimens and the shell, particularly males, may be easily confused with *A. ligamentina*. Johnson's (1980) *L. powelli* from the Black River, Missouri (MCZ 271445) is an unrayed *L. radiata siliquoidea* (Barnes) (see Utterback, 1916: Fig. 103A and B).

Recently, we have located small populations of *Lampsilis powelli* in the upper Saline and Ouachita river basins within the Ouachita Mountains division of the Interior Highlands of Arkansas (Fig. 1). With the exception of the previously noted topotypes and a lot in the Ohio State University Museum of Zoology (OSUM 21496: *fide* Stansbery, 1983), these are the only localities for this species which we have been able to substantiate. Considerable past habitat has been inundated by recent impoundments (not shown in Fig. 1) which periodically utilize hypolimnetic discharge. One population is presently downstream from DeGray Reservoir, a multi-level release facility, and several others are jeopardized by proposed impoundments. With regards to the above and the restricted range of *L. powelli*, some protected status appears warranted to ensure the survival of this species.

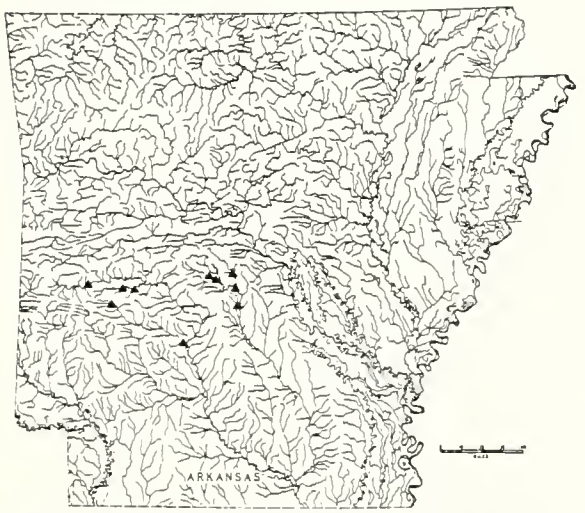

FIG. 1. Distribution (▲) of *Lampsilis powelli* (Lea) in Interior Highlands of Arkansas.

In concordance with Johnson (1980), the shell does resemble *L. virescens* (Lea), although convergence of shell characters may mask true phylogenetic relationships, and may be confused with *L. hydiana* (Lea), *L. radiata siliquoidea*, and *L. teres* (Rafinesque). Distinguishing characteristics between these species were discussed by Johnson (1980). In addition to *L. teres*, occasional specimens of *L. hydiana* and *L. radiata siliquoidea* may also be totally rayless. Generally, the shell of *L. powelli* is relatively thinner and the posterior ridge of males is more angular than those of the former species. *Lampsilis powelli* does sometimes exhibit a superficially rayed appearance. This is not pigemented periostracum, but a curious serial progression of minute pits arranged radially on the shell. Johnson (1980) additionally noted a resemblance to *L. reeveiana* (Lea); however, this species is not sympatric with *L. powelli*.

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